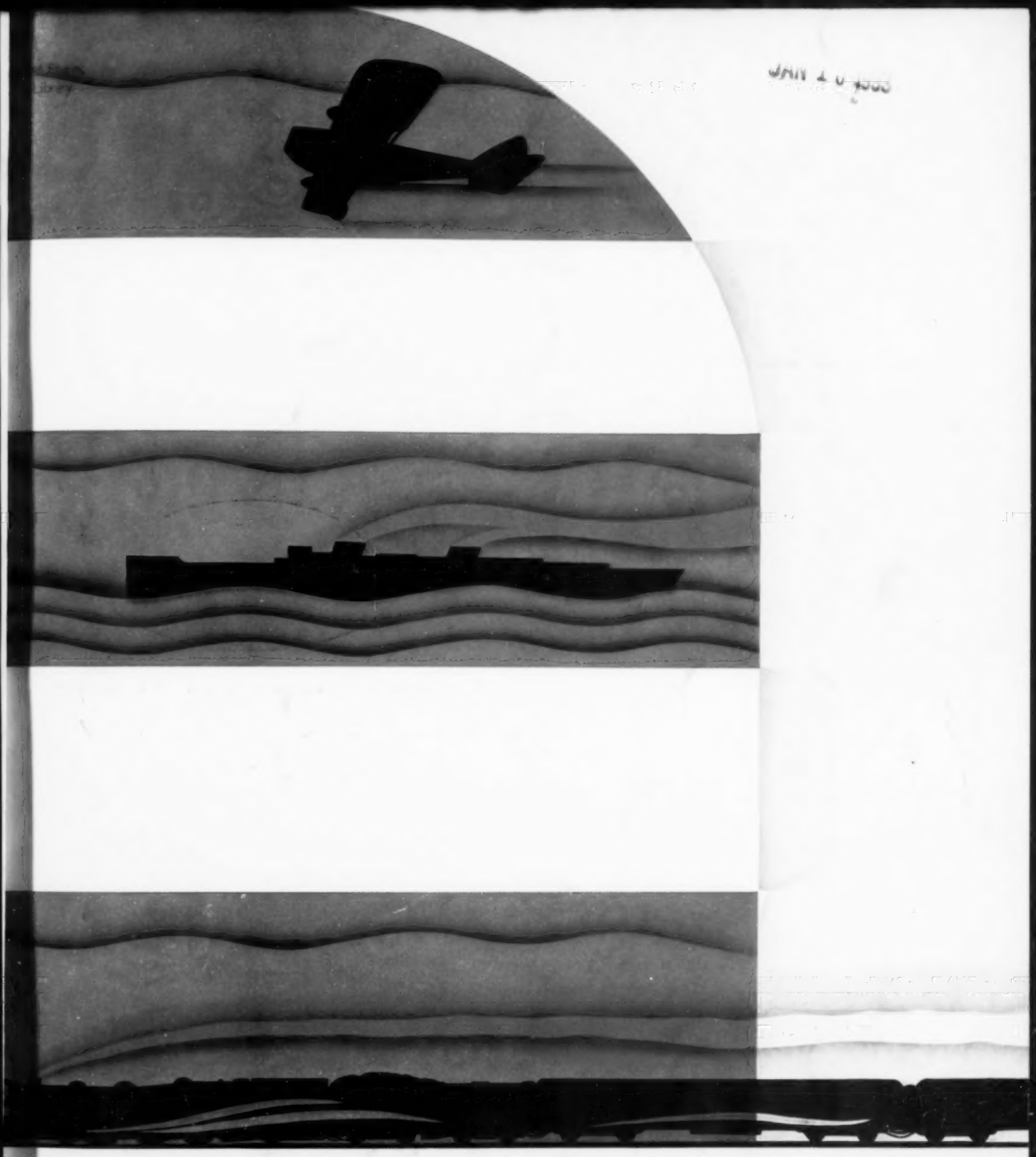

METAL PROGRESS

JANUARY 1933

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January, 1933

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Ernest E. Thum, Editor

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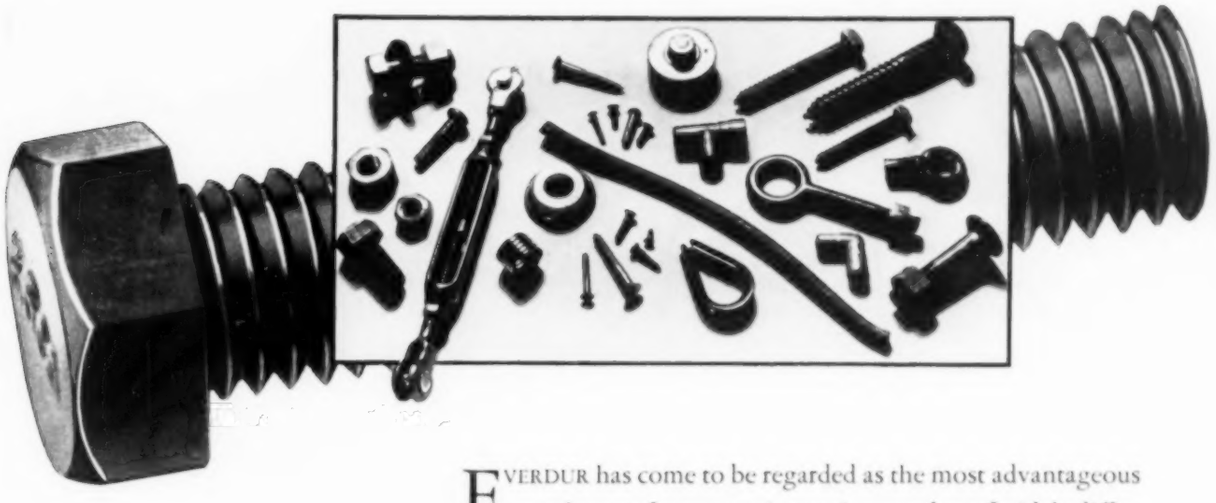

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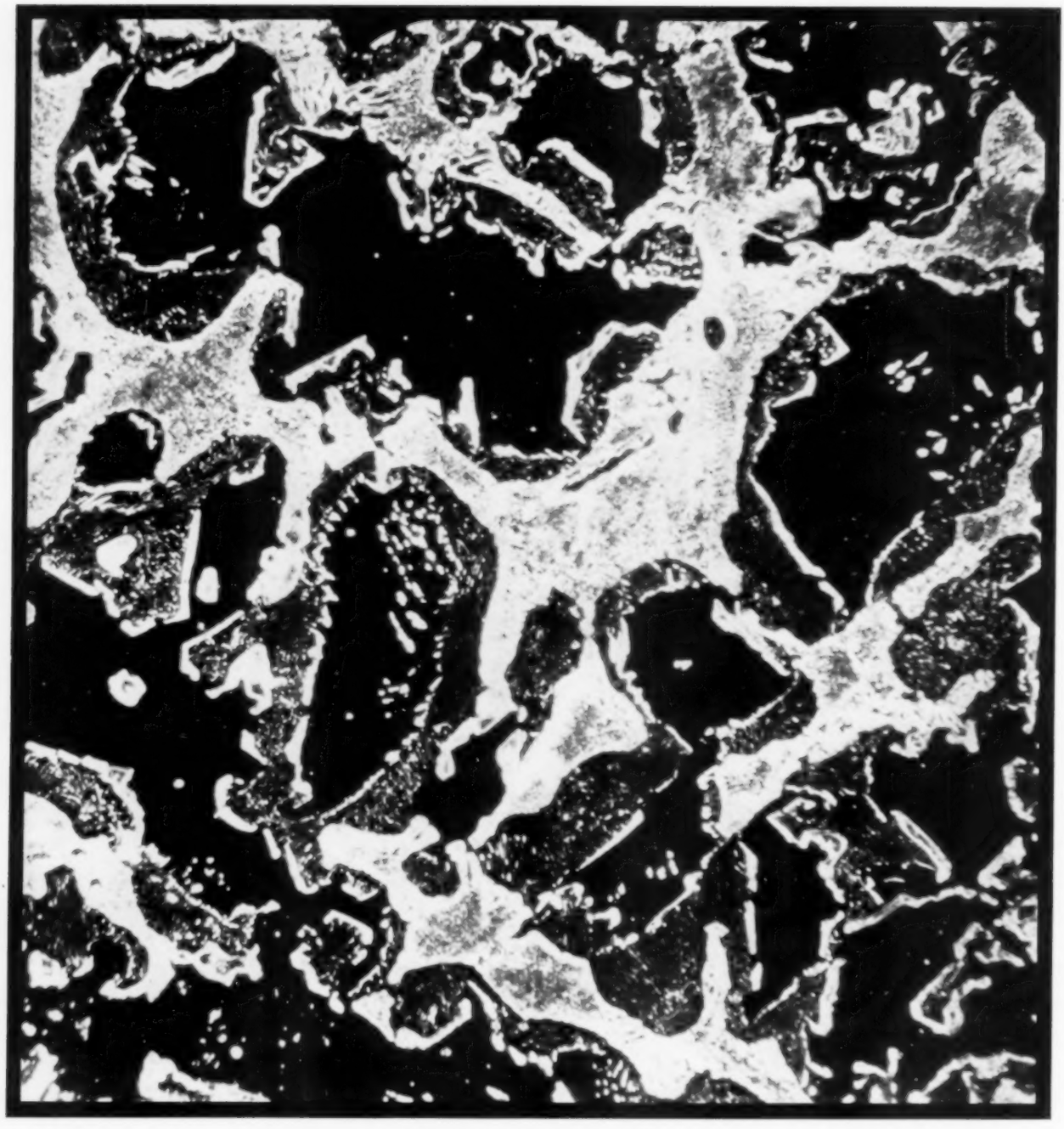


Micro by Guthrie and Comstock

Alloy of Iron, Chromium, Carbon

Darkfield Illumination, Described on Page 19, Brings Out a Eutectoid Between Light Colored Eutectic and Black Solid Solution. This Eutectoid Is Practically Invisible Under Bright Field Illumination. Magnified 960x

HEAT TREATING GEARS

in cyanide pot

& drawing oven

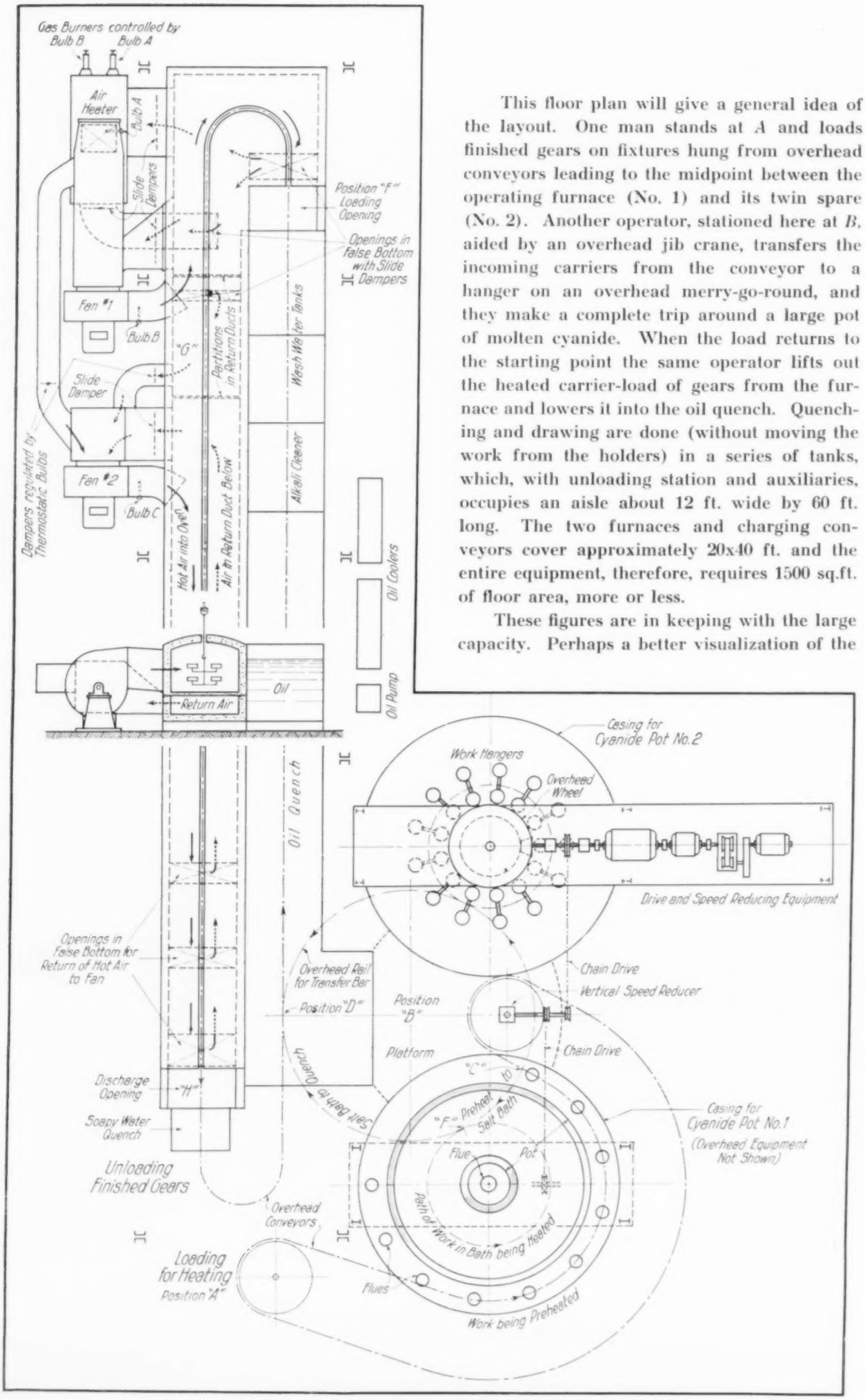
by E. M. Kingsley
Muncie Products Division
General Motors Corp.

AS A RESULT of a continuous study of the quality of gears for automotive transmissions by Muncie Products Division and associated units of General Motors Corp. it was decided about two years ago that better production costs and operating results could be achieved by a radical change in the heat treatment department at the plant in Muncie, Ind. Up to that time the operations were briefly as follows: Upset forge S.A.E. 5150 steel, anneal, finish machine, copper plate to hold scale to a minimum, heat in electric furnace to 1510° F., quench in oil, remove plate in electrolytic bath, and finally draw at 425° F.

As the result of an extensive investigation into many phases of gear manufacture, we decided that a preferred routine would be to forge the S.A.E. 5140 steel by upsetting, anneal at 1650° F. to approximately 195 Brinell, finish machine, preheat to 600° F., heat in cyanide or "aerocase" to 1525° F., quench in oil at 100° F. or less, clean, and draw in air at 450° F. This gives a gear of 65 to 75 scleroscope hardness. The method of heating and drawing prevents the formation of any scale on the surface; warping is so small that the gear, after a final lapping operation, will pass inspection for size and may be matched with others and assembled for silent running.

Cyanide heating baths not only prevent scale, but also any slight surface decarburization which sometimes occurs in even the most carefully controlled muffle furnaces. In fact, molten cyanide definitely carburizes the surface layers about 0.005 in. deep in a half hour, and this extra hardness undoubtedly improves the serviceability of the gears.

The problem then before us was to devise and install cyanide hardening and air drawing equipment capable of handling 100 transmissions an hour — approximately 1800 lb. of gears. Rather than buy a number of small capacity units, such as commonly sold by furnace builders, we decided to magnify the size, and adapt commercial conveying equipment so that a single furnace, quench, and draw (attended by two men) would handle the entire production. This article will describe the installation, built to these general specifications by Continental Industrial Engineers, Chicago, and which has been in successful operation for more than a year.

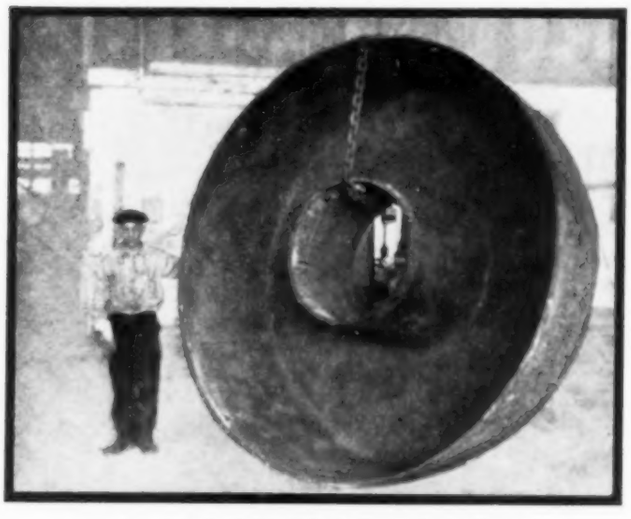


This floor plan will give a general idea of the layout. One man stands at *A* and loads finished gears on fixtures hung from overhead conveyors leading to the midpoint between the operating furnace (No. 1) and its twin spare (No. 2). Another operator, stationed here at *B*, aided by an overhead jib crane, transfers the incoming carriers from the conveyor to a hanger on an overhead merry-go-round, and they make a complete trip around a large pot of molten cyanide. When the load returns to the starting point the same operator lifts out the heated carrier-load of gears from the furnace and lowers it into the oil quench. Quenching and drawing are done (without moving the work from the holders) in a series of tanks, which, with unloading station and auxiliaries, occupies an aisle about 12 ft. wide by 60 ft. long. The two furnaces and charging conveyors cover approximately 20x40 ft. and the entire equipment, therefore, requires 1500 sq.ft. of floor area, more or less.

These figures are in keeping with the large capacity. Perhaps a better visualization of the

size may be had from the view below of one of the cyanide pots, undoubtedly the biggest "doughnut cutter" in existence, and possibly the world's largest casting of a heat-resisting alloy. It is 8 ft. 8 in. outside diameter; 1¼ in. thick; the central hole is 2 ft. 8 in. diameter; and the circular channel, which is 3 ft. wide by 3½ ft. deep, contains about four tons of cyanide.

The brickwork setting conforms generally to the outside of this pot, and the entire masonry is contained in a steel tank or binding 12 ft. 3 in. diameter by 6 ft. 9 in. high. Metal plus cyanide is so heavy that the pot cannot be hung from its lip, but is supported on a number of small corbels or piers catching the bottom edge of the inner and outer circle. Heating is done by four Maxon Premix burners, made locally. They produce a luminous flame by so-called "diffusion combustion" of natural gas. Burners are placed tangentially and induce a swirling flame in an annular combustion chamber immediately under the deep part of the pot. Hot furnace gases then work up on all sides of the pot, and blow off vertically from one central flue and from a series of equally spaced ports in the outer wall. The setting is hooded by extending the furnace binding plates, except for working doors, up about 7 ft. The top is closed and the gases and cyanide fumes exhausted through a 25,000-cu.ft. fan to a chimney, thus effectively clearing the air in the heat treatment department. Many of these details are shown in the half tones on pages 16 and 17.



Huge Pot, Shaped Like a Doughnut Cutter, Holds Four Tons of Cyanide

As shown on the plan, two identical furnace units are built side by side, one for use when repairs to the other are necessary. Life of the pot will, of course, depend upon the condition of the brickwork and mode of combustion — any hot spot will be ruinous. We have obtained an average pot life of 2000 hr. in 12-hr. shifts; probably this would be 15% longer if conditions enabled us to operate continuously.

Gas burners are controlled automatically by a device requiring two thermocouples, one bathed by hot furnace gases near the top of the setting, the other dipped in the cyanide bath. Double control of this sort prevents "over-shooting" or "hunting," and the bath temperature is held steadily hour after hour, between 1518° and 1526° F. The bath is analyzed daily and sweetened with fresh cyanide to an analysis of 25% NaCN. Excessive volatilization is prevented by a layer of powdered graphite. Radiation is further prevented by a series of insulated segmental castings, attached to outer and inner edges of the setting, covering the bath three-quarters of the way around except for a narrow central slot for passing the hangers.

A concrete foundation slab for the furnaces was poured on the building floor, so all the equipment (including gas and air lines) is above ground where it is readily accessible for inspection and cleaning. A platform made of subway grating raises the furnace operator at *B* to a correct level.

¶The plan, and the photograph on page 17, show the conveyor for carrying machined gears to the furnace. Hangers attached to every other roller carry a cast steel spider or rack weighing 45 lb. on which the operator at *A* places a definite number of gears weighing approximately 60 lb. The chain conveyor is driven ahead one station at 2-min. intervals; spacing is such that as the load works around the furnace housing to the unloading point *C*, the hanger is spotted successively over the outer flues in the furnace setting, so the cold gears are preheated by the uprushing furnace gases. Reaching position *C* the gears have attained a temperature of about 600° F. and are ready for the salt bath.

The operator stationed at *B* transfers the racks with a long lever, claw at one end,

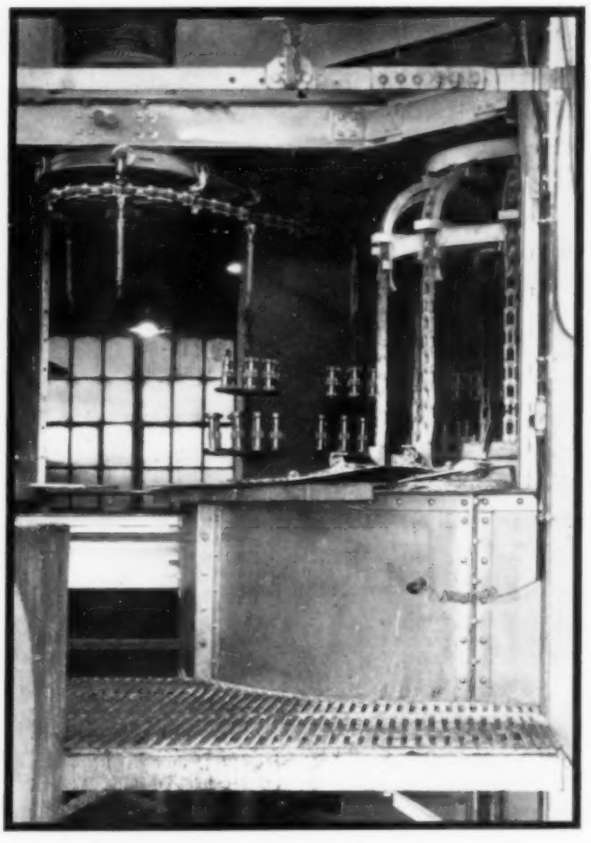
handle at the other, and supported at the fulcrum from a long air cylinder hung from a circular trolley track overhead. This lever handle has four push buttons controlling four motions: Fulcrum up, fulcrum down, lever swing right (from furnace toward quench), lever swing left (from quench toward furnace).

Suppose it is time to remove a heated fixture-load of gears. The operator hooks the claw of his lever under a boss on the fixture stem, raises the load out of the cyanide, swings lever right to position *D* immediately above the oil bath, lowers lever so the hot gears dip into the oil, and hangs the fixture on the second conveyor serving the quench and draw tank. Lever is then swung left to position *C*, where it waits a load of preheated gears, and these are moved over to *E* and lowered into the cyanide.

The photograph on this page shows part of the overhead merry-go-round that carries the gears through the salt. Hooks for supporting the load in the salt bath are hung from roller chains, which in turn pass over stirrups above, and are counterweighted at the far end. An empty hook is therefore up, out of the way of an incoming load of gears.

The overhead merry-go-round, only part of which is shown in the view, has 13 hangers equally spaced. Its entire weight, together with 13 loaded racks of gears, is carried from a bull wheel pivoted in a structural frame at the exact center of the furnace, and turning on a roller thrust bearing. This wheel and approach conveyors are geared together and driven by a single motor, operated intermittently by a program-control clock. At intervals of two minutes, therefore, the approach conveyor moves ahead one station and the merry-go-round simultaneously turns 1/13 of a circle. In the next two minutes the workman at station *A* unloads a rack of gears coming out of the draw, transfers the empty rack to the loading conveyor, and fills it with work. The workman at *B* transfers one hot rack of gears from bath to quench, and replaces it with a preheated load from position *C*. This load then is moved intermittently around the pot, taking 26 min. in all to complete the circuit. This gives not only ample time for thorough and uniform heating, but drives in a carburized case.

Equipment for quenching and drawing these gears is notable for its size, but more so for the fact that it resembles, on the one hand, an automatic electroplating unit, and, on the other hand, a japanning oven. This is not so surprising when it is realized that oil quenching and subsequent cleaning involve transit of the articles from tank to tank, and that air drawing at 450° F. is really a form of baking, ordinarily considered a low temperature operation.



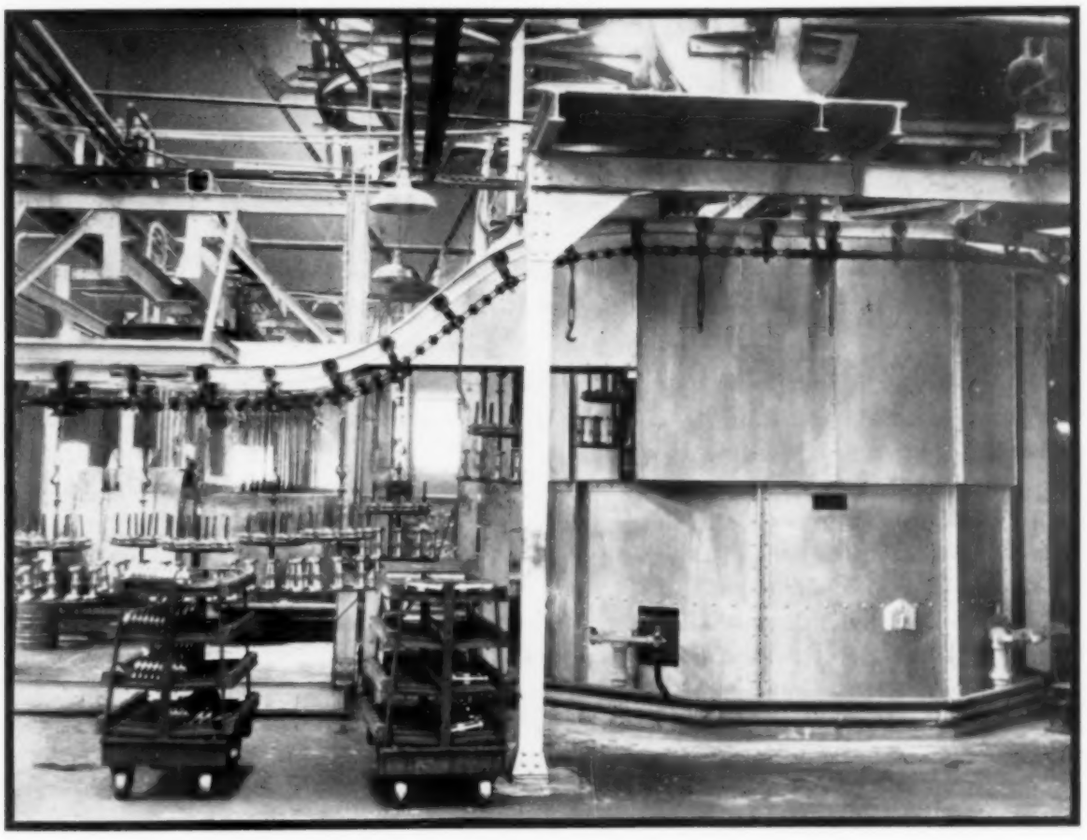
Operator's Position B. Loaded hangers spotted over flues inside furnace hood at rear. At right are counterweighted chains for carrying gears around cyanide bath

The photograph on page 18 shows that the unit is self-contained; the long, narrow tanks are fixed to the floor beams and the overhead conveyors carried by the same structural frame. Oil quench, cleaner, and wash water tanks are open at top, but the baking or air drawing unit is covered, except for a slot down the center through which the hangers slide. The chain conveyor serving this unit has a steady slow motion. Work hangers ride on pins sticking up from the top of the conveyor links, and when they approach the end of a tank, are

caught by a rotating arm, lifted up, transferred ahead, lowered on the other side of the partition, and landed on pins on forward links. These arms are geared to the conveyor chain at such a ratio that they make one complete rotation in the time required for the chain to advance the distance center to center of hangers. While the conveyor, transfer arms, and cam tracks are partially hidden by other details in the photograph, the mechanism has been so common in plating rooms that no further description is necessary.

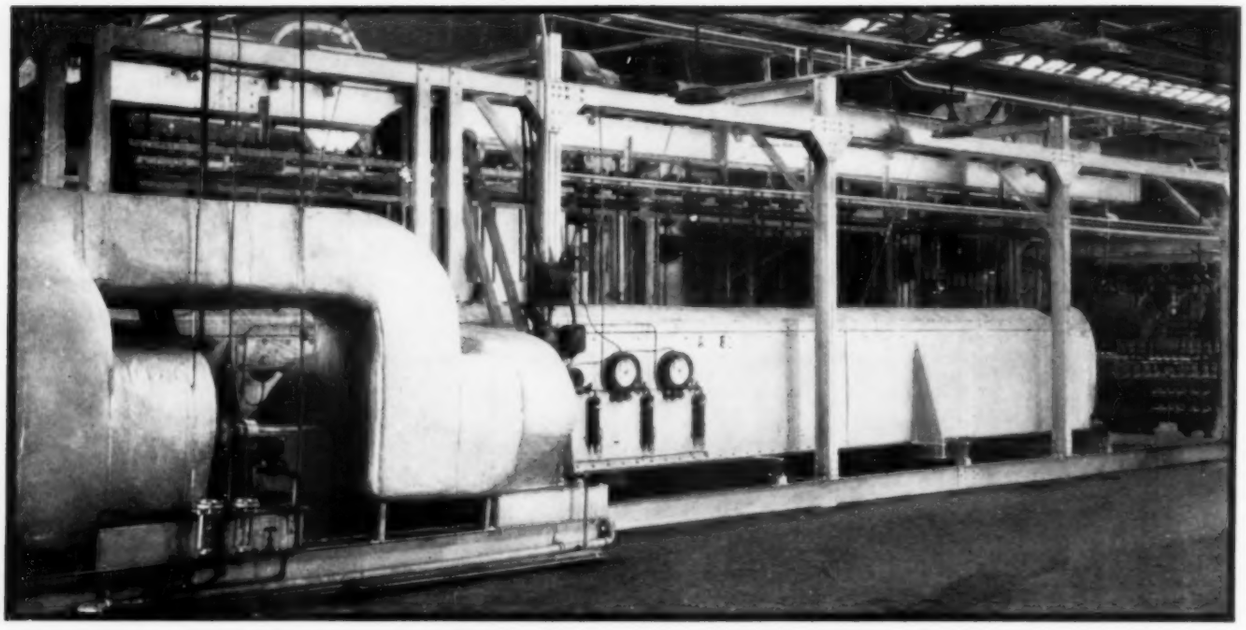
The oil tank is quite long, and the work remains in it over 30 min. This large size is justified by the large volume of quenching oil. This prevents any appreciable rise in local temperature when a fresh load of gears is quenched. General temperature of the oil is maintained at 100° F. by a pair of small surface condensers mounted alongside. Cooling water is circulated from a nearby pond.

Oily gears then pass through an alkali cleaner, then a pair of rinsing waters, and finally reach the beginning of the hot air chamber at *F* (see the plan on page 14). It takes about 80 min. to pass from here to the discharge end at *H*. In order to bring the work to drawing temperature as soon as possible, the entering end is maintained at 520° F., whereas the larger part of the travel (from *G* to *H*) is in air at 450° F., the correct degree. As can be seen from the photograph on page 18, all portions of this oven are adequately insulated.



General View of Semi-Automatic Unit. Loading station in left foreground and carriers enter furnace hood at left. In the background is end of quench tank, where hot work enters, and end of draw oven alongside at extreme left, where finished gearing is finally unloaded

A false bottom is built end to end, and the hot end (*F* to *G*) and the cool end (*G* to *H*) each has its own circulating fan. By referring to the plan drawing it can be seen how hot air from the housing of fan No. 1 is discharged sidewise into the oven and deflected so it travels against the work toward the loading opening. Just before reaching there it is drawn down through an opening in the false bottom and returns toward the fan, which it reaches by



Air Drawing Oven and Conveyor System; Hot Air Fans at Left

way of the air heater. The fan is operated so that the pressure inside the drawing chamber at the loading opening is just about equal to the atmosphere, so there is no great loss of heat by blowing off hot air or sucking in cold.

In a similar manner fan No. 2 blows hot air into the cooler end of the oven, and it travels with the work to the end, where it is drawn down through three slots in the false bottom, thence returning to the fan housing in the lower compartment. There is a tight partition in this return duct between intakes for the two fans, so one cannot steal the other's air. A dead area between the discharge of the two fans is prevented by cutting a narrow slot in the false bottom near fan No. 1 and drawing hot air through this direct to the inlet of fan No. 2 by an auxiliary duct.

Even with the best adjustment of pressures there will be some hot air escaping or some cold air entering through the slot and end openings. Also radiation losses must be replaced, and the heat carried out by the hot work and its supports. For this purpose an air heater is provided alongside the fans. This merely consists of an insulated chamber in one end of which are two gas burners. One burner is controlled by a hot bulb placed in the passage from this chamber to fan No. 1, and the other on the discharge of fan No. 1. A similar pyrometric control placed in the discharge of fan No. 2 controls the temperature of the cool end of the drawing oven by controlling a damper in the air passage from the air heater to the fan suction.

After the drawn gears come up out of the end of the oven, they are dipped into a soapy water solution to cool them for comfortable handling and to give them a film which is mildly corrosion resistant and will protect them from rusting for a few days if they are delayed in reaching the lapping machines. Each gear is inspected for hardness by scleroscope and must fall within limits of 70 to 76.

This equipment has been operating long enough to prove that it is capable of obtaining the improvements to the product which were originally anticipated. Furthermore, costs are satisfactory. Based on an average day, operating 12 of the 24 hr., the principal items (exclusive of burden) are as follows:

Labor, 2 men, 12 hr. each @ 50¢	=$12.00
1000-B.t.u. gas fuel, 46,800 cu.ft. @ 42¢/M	= 19.66
Cyanide, or Aerocase	= 37.75
Power and miscellaneous supplies	= 9.80
Total	$79.21

In 24 hr. the equipment (operating half of the time) will heat treat 21,600 lb. of finished gears. The cost per pound, therefore, figures to 0.367¢, say one-third cent.

DARKFIELD ILLUMINATION

adds contrast & resolving power

by W. Zieler
E. Leitz, Inc., New York
Photomicrographs courtesy of
R. G. Guthrie & J. A. Comstock

MICROSCOPY, in the hands of modern scientists, has expanded to so many different methods of analysis that sometimes mere magnifying power plays a subordinated role. The mineralogist for instance uses the microscope for a complete diagnosis of optical properties such as refractive index, bi-refringence, and other factors where the magnification of details is incidental.

It is noteworthy that in the microscopical analysis of metals, the instrument so far has been almost entirely restricted to magnifying small structural details. This limitation is usually justified by the opaque character of the specimens. Whether this is an insurmountable obstacle or not might be questioned, yet it is true that efforts made during the last decade to obtain better results were almost entirely directed toward what might be called high power magnification metallography.

In attempting to reveal finer structures, the metallurgist could benefit by the investigations which had established the laws regarding the resolving power of his instrument in transmitted light (making certain allowances for the fact that he was seeing reflected light from the specimen, rather than transmitted light through the specimen). We know for instance that the power of the objective to make small details distinguishable depends upon the wave length of the illuminating light and the numerical aperture of the objective. The relation is such that with increasing numerical aperture and decreasing wave length, finer structures can be resolved.

Efforts to increase the resolving power by shortening the wave length (using ultra-violet light) have been disappointing, except for a handful of men having extraordinary skill. The practical difficulties are manifold; focusing with invisible light is cumbersome, the reflecting power of metals in ultra-violet differs from that in visible light, making interpretation difficult; furthermore, the equipment is expensive. After years of experimentation, it seems that ultra-violet microscopy of opaque metals has not led to any startling discoveries not evident to first-class work with visible light.

In attempting to improve the resolving power by increasing the numerical aperture of the objective, one meets with definite limitations. Numerical aperture increases in proportion to the angle of the cone of light entering the objective and also to the refractive index

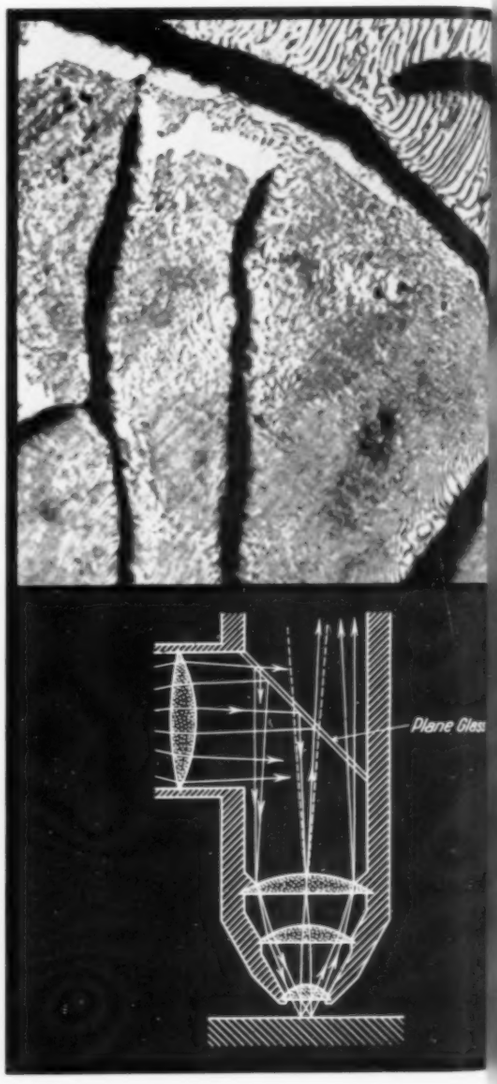
of the medium between object and objective. The cone of light cannot be increased beyond a certain limit. It was therefore necessary to immerse the objectives in liquids of higher refractive index than air, but work in this direction has been disappointing. Oil immersion objectives are frequently employed, but in my opinion, have not led to noteworthy results.

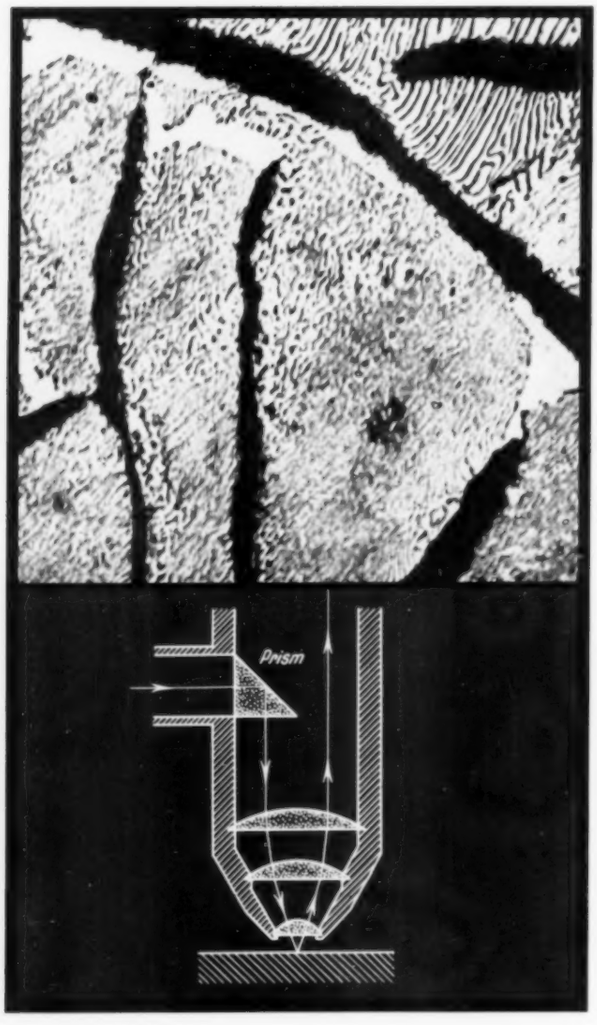
In many of the efforts to increase the resolving power, one important factor was overlooked—that the operating conditions in reflected light are not exactly equivalent to those in transmitted light. Since metal specimens are opaque, it is necessary to construct the well-known vertical illuminators, where the light, entering the observation tube at right angles to the optical axis, is reflected by means of a prism or a glass plate, and passes through the objective onto the specimen. From there it is reflected directly back and passes a second time through the objective. Therefore the objective fulfills a double purpose; (*a*) it acts as a condenser and (*b*) it acts as an image-forming observation system. This double duty is responsible for some haziness in the images.

Another factor, often overlooked in the microscopy of reflected light, is that the resolving power depends not only upon the numerical aperture of the objective, but also upon the numerical aperture of the illumination system.

The glass reflecting prism used for the vertical illuminator affects the numerical apertures of both the illumination and the observation system, as shown by the cross-section through the tube of a microscope sketched in the figure at the left. In directions parallel to the edge of the prism (perpendicular to the type lines) the full numerical aperture of the objective is available, whereas in the direction at right angles only one-half of it can be used. Particu-

Plane Glass Reflector Opens Entire Aperture for Illumination as Well as for Observation, but Contrast Is Lost Due to Scattering of Rays. Micro of same spot of iron as photographed at left and at right shows the result





If a Prism Is Used for Vertical Illuminator It Cuts Down the Resolving Power in the Direction Parallel to Its Edges. Micro of cast iron at 360 diameters

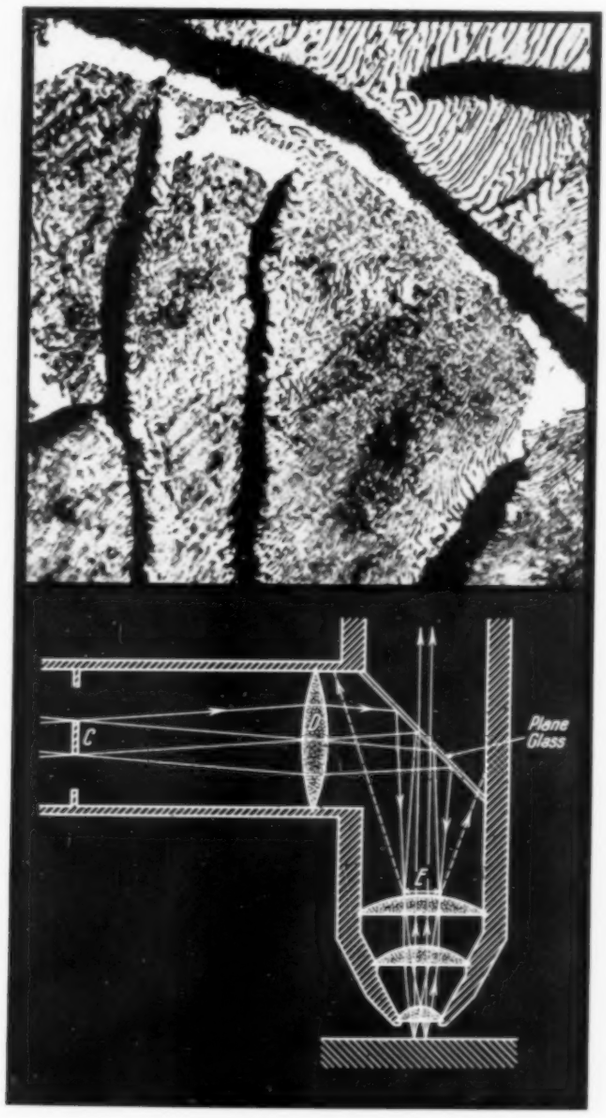
Conical Illumination, Shown on Page 21, Improves the Contrast by Using Sides of Objectives for the Illuminating Rays and the Central Portion for Rays Back to the Eye Piece

larly when using objectives of shorter focal lengths and higher numerical aperture, this irregularity of the resolving power is noted as an apparent distortion in the image.

In order to remove this distortion, manufacturers constructed plane glass illuminators (second diagram). In this device the glass plate acts both as a reflector and as a transparent medium. A portion of the light entering from the side is reflected down through the objective to the specimen. The sketch indicates that the entire aperture is now available for illumination as well as observation.

Metallographers know that the glass plate reflector has the great disadvantage of producing images lacking in contrast and often difficult to interpret. This shortcoming can be explained by the fact that not only the glass plate performs the double function of reflecting and transmitting light, but the curved surfaces of the lenses of the objective also reflect light. This is particularly true of those rays close to the axis of the microscope (see the dotted lines in the figure). Rays further away from the optical axis meet glass surfaces at a higher angle of obliquity, and any reflected portion is absorbed by the dull, dark interior of the metal tube. Though the possible resolving power is satisfactory, the haze over the entire picture greatly impairs the visibility of fine structural details.

Since this lack of contrast is quite disturbing, another way was found to overcome the difficulties inherent to a prism reflector. As seen in the figure on this page, it consists of inserting an opaque stop or bull's-eye *C* into the tube of rays at a definite distance from one of the illuminator lenses, *D*, so that an image of this stop is formed in the plane tangent to the rear lens of the objective at *E*. The center portion of the rear lens is not illuminated. Wherever the incoming light meets the border surface, obliquity is so high that the reflected portion is absorbed by the tube walls.



This system of lighting does not form a dark spot in the center of the reflected image, because diffusely reflected light from the specimen passes through the central portion of the objectives, and this most valuable part of the lens system consequently participates in the formation of the image. Brief consideration will show that the center portions of the objectives are only available for the numerical aperture of the observation system, but not for the aperture of the illumination system.

With this type of "conical illumination," photographs of excellent resolving power and contrast can be produced. In fact, since it permits a high numerical aperture of illumination and of observation systems, the contrasty photographs obtained with fine laboratory microscopes reveal just about as much information as can the equipment for ultra-violet light. The photomicrograph at 360 diameters accompanying the third sketch is evidence.

Up to the present time, metallurgical microscopes have not utilized the darkfield condensers well known to colloid chemists and bacteriologists. These were constructed for the examination of objects by transmitted light — colloid particles which were too small to be resolved in directly transmitted light, or bacteria that had escaped attention because they were either colorless or had the same color as the surrounding medium. The object was not to detect details within the particles, but rather to prove their existence.

A similar condenser has now become available for metallurgical microscopes, and this darkfield illuminator for reflected light is sketched in the fourth figure, on this page.

In contrast with any previously described type of illumination, none of the illuminating rays pass through the lens system of the objective, but are reflected from two spherical mirror surfaces to the specimen at a very oblique angle. In the other illuminators almost all the light striking the smooth surface of the specimen was reflected back into the observation system, but in darkfield illumination nearly all of it is reflected so obliquely that it does not enter the objective. Thus, an optically plane and structureless opaque surface appears perfectly black.

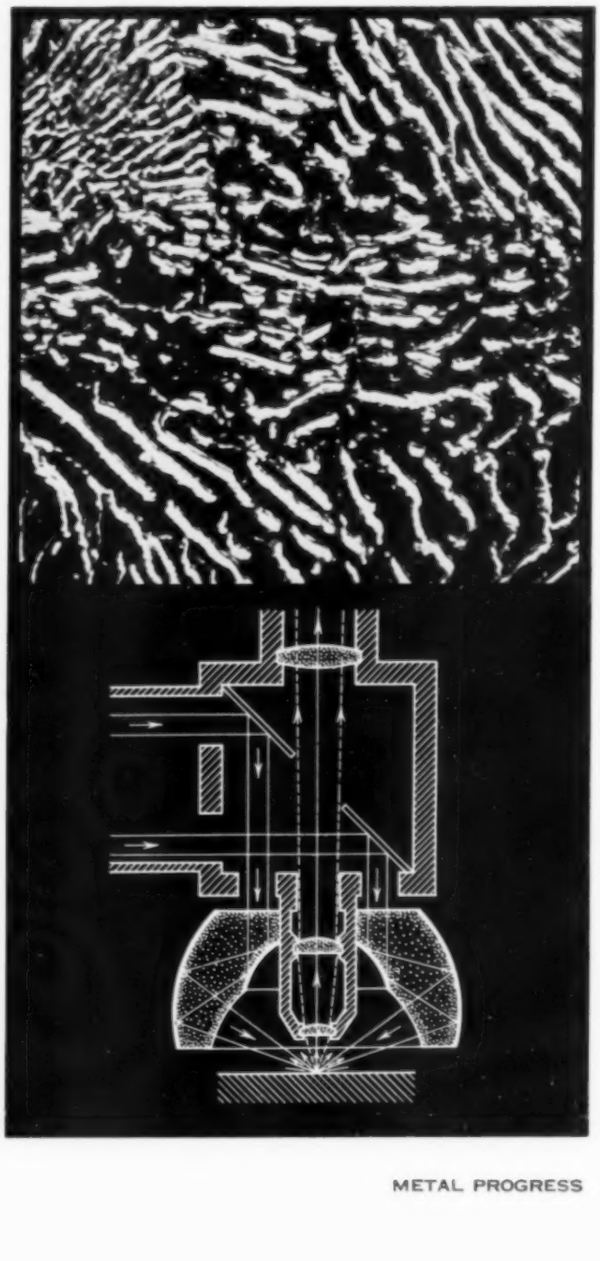
The smallest traces of internal reflections from lens surfaces, which are slightly disturbing even with conical illumination, are eliminated in darkfield illumination, because only such rays as are reflected from the surface structure of the specimen enter the microscope.

At first glance it may seem that darkfield illumination produces the exact reverse of vertical illumination — a dark area is a flat surface and a light spot comes from an inclined one. Even if this were the only feature, the darkfield illuminator would still have the added advantage of better rendition of contrast. See, for instance, the frontispiece, page 12, a photomicrograph clearly showing a constituent all but invisible by vertical illumination. If we remember that the resolving power of the microscope depends not only upon the numerical aperture of the objective, but also upon that of the illumination, it is evident that the new device must give an increased resolving power, which, with the perfect contrast, is of immense value.

The sketch shows that it has been necessary to redesign the objective mounting to pass the incoming light rays outside the lens system. The lenses themselves have been changed to conform to the new circumstances.

It may be remarked that in so doing one inherent defect of the plane glass reflector has been removed, a defect which is real, although one which might easily escape the attention of the metallographer. Rays from a point on the

Darkfield Illumination Brings Light in Obliquely, Thus Reserving Entire Lens System for Observation. In the micro of lamellar pearlite at 2400 magnifications the carbide plates stand out and photograph white on the edges. Intervening ferrite, being flat, reflects no light into the objective and consequently is dark. Note the numerous tiny particles of carbide appearing throughout the lamellae of ferrite as white specks



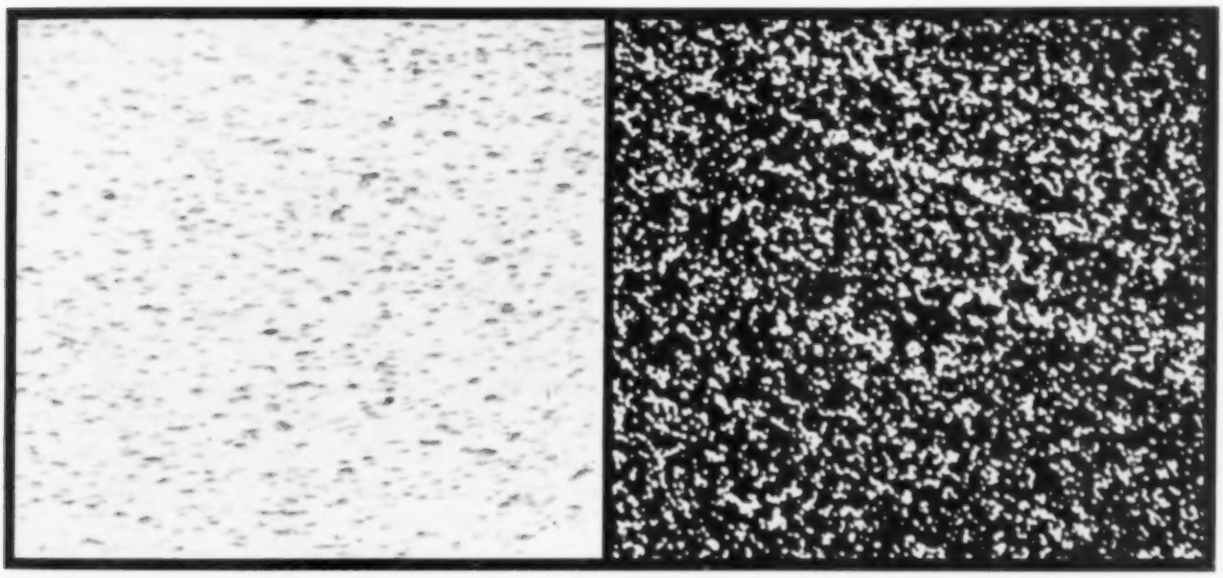
object, passing from the objective through the glass plate to the eyepiece, are disturbed into a slightly convergent bundle so they cannot be accurately focused at a mathematical point. This lack of focus is known as spherical aberration. It becomes more disturbing with increasing thickness of the glass plate; however a plane glass reflector cannot be cut too thin because it then cannot be made an optical plane.

Darkfield condensers introduce a glass block of great thickness into the course of the rays, causing so much spherical aberration that the old series of objectives cannot be used. New ones "corrected for infinity" (in ocular parlance) cause the divergent bundle to become parallel and entirely eliminate the undesirable spherical aberration. It is now possible to supply thicker reflecting glass plates which are optically plane, avoiding not only the spherical aberration of plane glass but also the distortion of the image from slightly warped glass which could arise in vertical illumination.

However, it would appear that the most attractive feature of darkfield illumination is that in many instances the image revealed deviates from being an exact reversal of that obtained with vertical illumination. It is therefore possible to compare the brightfield image of a specimen with its darkfield image, and draw conclusions by studying the different appearances. Thus, darkfield illuminations seem to offer for the first time the possibility of extending the microscopical analysis of metals beyond the mere magnifying of small details. Plane surfaces of any constituent or inclusion appear black. The reflecting power (or color) of an object for vertical incidence of light is immaterial. The darkfield image accurately portrays the surface relief; wherever there is darkness in the image there is also complete smoothness on the surface.

Many comparative views made of identical spots of various alloys, whether unetched, etched, or heat tinted, prove the above statements. Space permits reproduction of only one pair. They show the same spot on a polished and unetched specimen of high speed steel. One was photographed with brightfield illumination under the most favorable conditions to bring out the slightly relieved tungstides and carbides in contrast with the polished matrix, and yet the delineation of these particles is very poor and unsatisfactory. The companion figure brings them out in maximum contrast and in the greatest amount of detail, as can be judged by the number of very small particles appearing in a given area.

Thus, darkfield illumination offers many advantages, particularly if used as a supplementary method of illuminating the specimen.



Same Spot of High Speed Steel, Magnified 175 Diameters. Not etched. Carbides are hazy and hard to photograph under vertical illumination. Darkfield illumination brings them out strikingly and in great number

FINISHES FOR ALUMINUM

lustrous surfaces

for ornamentation

by T. D. Stay
Technical Director
Castings Division
Aluminum Co. of America

THE large number of surface finishes that have been developed for aluminum afford the architect an additional opportunity to impart character to an extremely versatile metal. Many characteristics that influence its use in architecture are well known: It is light in weight, possesses a high degree of resistance to atmospheric corrosion, and does not drip-stain adjacent parts; the metal may be cast, forged, rolled, drawn, stamped, spun, extruded, and machined with comparative ease, its ready workability making it available in practically all the forms known to the metal working art.

A most attractive feature to architects is the fact that its color is permanent and gives them contrasts that are not possible in cast iron and bronze. Black marble and white aluminum have been used very frequently and most effectively.

Finishes for architectural aluminum include various changes in color and texture. The natural color is silvery, with a slightly bluish cast. However, there is a difference in the intensity of the bluish tinge in the several commercial products. A casting, for example, will appear darker than an extruded shape because of its coarser texture; but both may be polished to substantially the same "color."

While the texture of an aluminum ornament has a slight influence on its original color tone, it becomes more significant on being exposed to the atmosphere for any appreciable length of time; the bright, silvery luster becomes less pronounced and the surface loses its high degree of reflectivity for light. This is due in part to the formation of an oxide film, which serves as a protective coating against further oxidation, and in part to the accumulation of dust and dirt from the air. Obviously, if the surface is coarse in texture, foreign particles in the atmosphere will collect more easily.

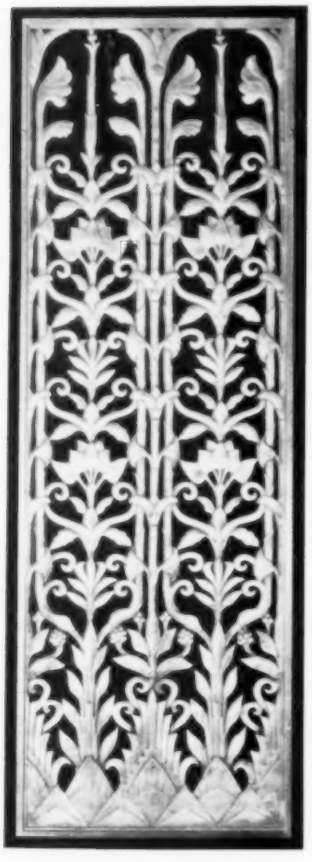
Architectural finishes are applied by either mechanical, electrochemical, or chemical means. In general, they can be used in connection with all types of aluminum commodities, although, of course, there are certain detailed exceptions both in the method of application and in the results obtained.

Architectural castings are seldom erected in the "as-cast" condition because of irregularities in color and texture. As the castings come from the sand, they often show a surface dis-

coloration at the points where they are gated and risered. Then, too, the sand on the mold facing may crack slightly as the metal is poured and this will cause a small surface blemish. Such "sand cracks," as these surface irregularities are commonly called, must be removed by grinding and a ground surface always appears lighter than the remainder of the casting. As a result, it can be said that the preparation of castings for finishing starts in the cleaning and trimming rooms of the foundry.

Sand Blast Finish — Probably the most common finish for aluminum is that produced by sand blasting. It gives a uniform surface texture with slightly less reflectivity for light than the "as-cast" surface of a casting or the "as-rolled" surface of sheet or plate. Sand blasting also serves as a base for many of the other finishes.

The texture of the sand blast finish depends upon the size and type of sand employed in blasting, the pressure, the size of the nozzle, the angle of impact, and the distance the nozzle is held from the work. In general, three different grades of sand blast finish are used and these may be classed as coarse, medium, and fine. A pressure of 60 to 90 lb. per sq.in. is usual practice.



Architects: Weary and Alford, Chicago. Panels, sand blasted with satin finish

The coarse finish is, as a rule, used in preparing surfaces that are to be de-plated (as described next) but its use is otherwise somewhat limited because its heavy abrasive action warps large thin sections too much. The finer sand blast finishes produce a surface that may be easily high lighted or satin finished, since the milder abrasive action reduces the grinding and polishing work subsequently necessary.

De-Plated Finish — The dark, slate-gray color of the de-plated finish is obtained by anodically treating ornaments fabricated from the aluminum-silicon alloys after they have been properly sand blasted.

This process is carried out in a special electrolyte in which the piece to be treated is the anode. When electrolysis takes place, the silicon particles in the alloy are exposed and an oxide film formed on the aluminum. The details of the operation, such as composition of electrolyte, temperature, and current density, form a proprietary process.

De-plated finish has proved extremely popular for spandrels, since its color resembles that to which aluminum will eventually weather. At a distance it is similar to that of window glass; thus the spandrels merge with the windows and give the appearance of continuous gray lines. The de-plated finish also serves as an excellent background for ornaments and spandrels in which the points of accent are to be high lighted by polishing, buffing, wire brushing, or satin finishing.

Polished Finish — Polishing materially increases the reflectivity for light and imparts a truer silver luster to the metal. Since the surfaces to be polished must be uniform in texture, castings are first blasted with medium or fine sand. Various grades of emery or artificial abrasive are then used as abrasives, either on wheels or belts. For rough work, No. 60 to 120 grain is employed, while for finishing

Grille for Prospect High School, Pittsburgh. Architects: James T. Steen and Sons. Sand blast finish

work, a wheel with No. 140 to 180 grit is used.

The size of the wheel depends upon the size and shape of the surfaces to be finished. In general, it is from 6 to 12 in. diameter and 1½ to 2 in. thick. Either muslin, canvas, felt, leather, or composition buffs are used in making up the wheels. The surface of the wheels is painted with glue and the emery embedded into it. For best results, the wheels should operate at 3400 to 4400 r.p.m. No lubricant is used with the coarser wheels. Buffing tallow is, as a rule, employed with the No. 120 and 140 grit wheels and greaseless polishing compound with the No. 180 wheel.

Abrasive cloth belts are, of course, limited to plain, flat surfaces. Where they are used, they are generally made up with No. 80, 120, 140, and 180 grit. No. 0 buffing tallow and a small amount of machine oil serve as satisfactory cutting lubricants, although a thin paste of paraffin and turpentine may also be used for certain work.

Buffed Finish — This is nothing more than a continuation of polishing, using finer grades of emery and such polishing greases or coloring compounds as Tripoli or slaked lime. This type of finish is generally employed for interior work, because of its high luster.

Wire Brush Finish — As the name implies, the wire brush finish is produced by scratching the surface with a rotary wire brush. The large number of scratches on the surface, all running in the same direction, give a luster less brilliant than that obtained by polishing but in no way as flat as that produced by sand blasting.

If the surface to be wire brushed is a cast surface, it is first blasted with medium or fine sand — fine sand preferably, but sometimes the more abrasive action of the heavier sand is required. Wire wheels are usually 6 to 10 in. diameter and operate at 450 to 600 r.p.m. The wires may be either aluminum, nickel, stainless steel, or nickel silver. The fineness of the finish, of course, depends upon the size of wire employed, and for most work, the wires are 0.006 to 0.014 in. diameter.

Satin Finish — There are a number of satin finishes for aluminum which differ from each other in texture and luster. Some are quite brilliant and approach the finish produced by polishing, while others have an almost matte-like surface and are less pronounced in their satin sheen.

A wire brush satin finish is one of the most common; it is somewhat similar to the wire brush finish but of a finer texture. As a result, it has greater reflectivity for light, and in effect gives the aluminum surface a satin sheen without the brilliant luster produced by polishing.

The piece is first polished. After using No. 180 emery, it is buffed with muslin or felt wheels to which a greaseless polishing compound has been applied. For the majority of the work, "grade N" polishing compound is gen-

erally used, but it must be remembered that the grain size of the abrasive in the polishing compound bears a direct relation to the texture of the resulting satin finish, and at times, it may be desirable to employ a finer or coarser abrasive. Large, flat surfaces should be given a mild sand blast at this point, for by so doing, a more uniform appearance will be obtained on subsequent wire brushing. The surface is then thoroughly cleaned of grease and dirt with a suitable solvent and wire brushed.

Brushes of Fine Wire

Rotary wire brushes for this purpose are made up of aluminum, nickel, stainless steel, or nickel silver wires, 0.004 to 0.010 in. diameter. Brushes are usually 6 in. diameter and operate at a speed of 450 to 600 r.p.m.

A finish closely resembling the wire brush satin finish can be obtained with No. 80, 120, 180, and 240 grit abrasive belts operating at a speed of 2400 to 3000 ft. per min. Such equipment is, of course, confined to flat surfaces.

Oxidized High Light Finish — This is a two-tone finish in which the background of the spandrel or other decorative detail is a dark, slate gray and the points of accent are a much lighter color, almost pewter gray. It is produced by sand blasting the ornament, polishing the raised portions, and then de-plating.

Cast Hammered Finish — Wrought aluminum can be hand forged to simulate an antique finish. A somewhat similar finish can be obtained on de-plated castings by hammering the surfaces and then producing a high light finish.

Combination Finishes — The oxidized high light finish represents but one of many combinations which can be obtained through the use of the standard finishes. Besides the standard finishes and combinations of them, many special ones have been developed for certain types and designs of ornaments. The illustrations of architectural units that accompany this article, while good, hardly are able to reproduce variations in reflectivity in the various parts. Really striking effects may be produced.

Painting and Lacquering — Aluminum may be painted and lacquered for decoration in much the same manner as other architectural metals. Normally, the only preparation that is necessary is to clean the surface of all grease and dirt with a suitable solvent, although improved adhesion of the paint film can be obtained by sand blasting the surface lightly or by anodically treating it.

Alumilite Process — This proprietary process opens up almost unlimited color finishes for architectural aluminum. It consists of anodically treating the surface to produce a heavy oxide film and then coloring the oxide with certain dyes and pigments. Since none of the dyed finishes is permanently fast to sunlight and weather, its use is largely confined to interior work; however, the application of oxide finishes, colored by mineral pigments, is being developed at the present time for exterior use.

Spandrel for Creighton University, Omaha; Leo A. Daly, Architect. Sand blasted, wire brushed and high lighted finish

Raw Material for Steel

One of a Series of Etchings Made by Otto Kuhler for Timken Roller Bearing Co., and Reproduced by Their Courtesy

EDITORIAL

NEW YEAR is here, and with it hope that 1933 will be far better than 1932. Statistics might be invoked to "prove" it, but the statistical indicators have turned out to be wrong so often that they prove nothing much but their own limitations. Any pronouncement for the next few months must be based largely on the knowledge that the American nation has been doing far, far less business than it is accustomed to, and that its present level of activities is so low that there is no other way to go but up. Also, that unless someone finds some fresh bogeyman to frighten the timid (that is, all of us), we will before long pluck up courage enough to say Boo! to those we now have.

ONE thing is sure, and that is that any estimate of the rate of expansion in the steel and metal industries based on pre-War or even pre-depression conditions is worthless. The dizzy climb has been checked. There are many reliable indications that the consumption of steel per capita in America, at least, is growing much less rapidly than in the 1900-1920 period.

First is a profound change in our methods of transportation. Prior to the War many miles of new railroad were being built in the Central and Far West. Since the War the desire has been to economize on operating labor and maintenance by longer trains and heavier equipment. Both these movements are complete, yet both (while they lasted) required huge quantities of steel and alloys for rails, bridges, signal systems, locomotives, and cars. Competition from automobiles and airships, pipe lines and electric transmission lines will prevent any further large expansion of the rail system; from now on the railroads will require metal principally for upkeep — obviously only a portion of the consumption in the recent years when they were the steel industry's best customers.

Associated with this expected decline in the railroads' consumption are the changes in the nature of the metals brought about by the automotive industry. In the new "rolling stock" weight is a great consideration. (The power plants on four sections of the 20th Century Limited are comparable with that in the frail racing craft, Miss America X.) This means that the bulky cast iron, machine steel, and boiler plate are replaced by aluminum, strong alloy steels, and sheet. Chilled iron wheels and steel tires give way to wood and rubber. In the permanent way, heavy rails are superseded by light concrete reinforcement, and massive trusses by spidery suspension bridges.

Trend in Steel Is Toward More Sheet and Wire

This change from the bulky and impressive to the light and sleek is also to be observed in all our modern machines, household equipment, and tools. Design is being continually refined, not only to improve portability, but to reduce first cost of raw material. Hence an ever-increasing amount of sheet and strip is being made into stampings, pressings, weldings, and casings, replacing more bulky forgings and castings. For this reason production of sheet and strip during the last four years jumped to 20% of the entire steel output in this country, as compared to 12 to 13% for the previous decade. (An accelerating cause, of course, has been large improvements in the production technique for flat rolled steel products.) If statistics were available they undoubtedly would show a similar trend in the non-ferrous industries.

AN OBSERVER might think that the tonnage lost to the changed transportation and mechanical industries would be regained by sales to other rapidly growing ones, such as the petroleum industries. This is in line with the fallacy that every man put out of work by a machine can find a job made by another ma-

chine. The real truth is that such sales of metal (except the remarkably steady, "depression-proof" outlet of sheet and tin plate for containers) comprise an increasing proportion of special alloys, more or less corrosion-proof. The ideal now is to put in equipment that will stay put. While only a little stainless steel is now being made, relative to the enormous amount of common steel which is rusting away each year, the tonnage is growing rapidly, as well as that larger tonnage of steel with low alloy content markedly resistant to corrosion. This means that, on the average, the steels now being made are lasting longer than 10 years ago.

One last important factor will contribute (in the near future, at least) to this slackening demand for steel. This is a stagnant condition in the building and construction industries, ordinarily consuming 15 to 20% of the American output. Despite all the propaganda that our trouble is "under-consumption, not over-production," it is becoming abundantly clear that we have developed so much power and invented so many labor-saving machines that the entire country's wants can be supplied when the entire population is working much less than the standard 8-hr. working day. Existing and enormous debts already owed America by other nations to the east of us, and a poverty stricken Orient will effectively prevent any outlet by export. America will therefore be in no position to expand her existing factories (except for newly discovered specialties) until such time as the working day can be drastically cut, and the mass of our people again happily and gainfully employed. Lacking powerful and militant labor unions, which in the past have forced such evolutionary changes, willy-nilly, this necessary and inevitable change will probably be unduly delayed.

WITH the above factors in mind, namely, stagnation in railroad and factory construction, the replacement of massive machinery by lighter, the development of rust and corrosion resistant steels, and the virtual impossibility of export we see ample reason for the decline in per capita production of steel in America. On the other hand, these very same factors indicate an increasing importance of the steels the readers of METAL PROGRESS are interested in, namely, heat treated alloy steels, corrosion resistant iron and non-ferrous alloys, sheet and wire products, and steels of high grade and high finish.

Consider the increasing proportion of thin material. Ten years ago one out of every four tons of ingots eventually was marketed as sheet, strip, tin plate, and wire. Now the proportion is one of three.

Growth of the alloy part of the steel family has frequently been remarked. In 1902, 2% of the total steel ingots and castings were alloy; the proportion is steadily climbing and has now reached 6%. (Collected statistics give a conservative picture, owing to the lack of an accepted boundary between plain steel and alloy steel.) Unquestionably the causes for this movement are continuing, and a constantly increasing proportion of the output will be low-alloy steels, heat treated to improve their physical properties. Each one of these will consume its proportion of the various ferro - alloys — chromium, vanadium, molybdenum, tungsten, silicon, manganese, titanium, and zirconium — and the pure metals nickel, aluminum, copper, and cobalt.

More & More Fine Steels and Alloys

An especially important phase of the future steel industry is the corrosion, rust, and heat resisting alloys. These have only lately been discovered, but no words are needed to remind readers in the consuming industries of the importance of reaction chambers of high nickel alloys, and of stainless iron to nitric acid plants, of high alloy preheater and exchanger tubes to petroleum refineries, of high chromium-nickel castings for handling sulphite liquors in the paper industry, and of the stainless steels to the food industries. These established uses will undoubtedly grow. The most spectacular advances are being made in the high chromium-nickel alloys, which have proven so enduring against hot gases that all manner of furnace parts are being made of them (even for high temperatures in the ceramic industries) such as containers, muffles, heat exchangers, conveying mechanisms, resistors, and burner parts. The enthusiast pictures the ovens, kilns, and furnaces of the future as made of a little brick, but mostly of metal and insulation.

FREE-CUTTING BRASS

machinability of the various alloys

by D. K. Crampton
and H. P. Croft
Chase Brass & Copper Co.

THERE exists very little published information concerning the machining properties of brass rod. Tables published by makers of machine tools are usually quite conservative, and refer only to the standard free-cutting brass rod, and not to other copper alloys. The following is an abstract of published information, together with some experimental work which has been done recently, and has been prepared from a manuscript for the forthcoming revision of National Metals Handbook. The large table on page 32 gives the nominal physical properties (of rods in drill temper) of a number of brasses and bronzes that are sometimes machined, a rough index of the heading and bending properties and machinability.

The word machinability is a general term, and is used here to indicate the approximate performance of various metals undergoing different machining operations compared with free-cutting brass rod, drill temper, as 100. Machining operations include turning, drilling, milling, planing, and sawing. Considerable deviation from these average percentages may be expected on occasion. One alloy may, for instance, turn readily, but tap less easily, due to the type of chip thrown off. Most of the data are averages of values obtained from several sources. Prof. O. W. Boston, in *Transactions*, A.S.S.T., 1929, states that experiments at University of Michigan indicate that the energies used in planing and drilling, plotted as a func-

FEEDS FOR FREE-TURNING BRASS ROD

Screw Machine Operations or Tools	Size of Drill	Feed per Revolution
Twist drills (Depth of cut: Under 5 diameters)	Under 1/16	0.001 to 0.004
	1/16 in.	0.004 in
	3/32	0.005
	1/8	0.007
	3/16	0.008
	1/4	0.010
	5/16	0.011
	1/2	0.014
	5/8	0.016
Forming tools: Rough work		0.0015 to 0.004
Finish work		0.001 to 0.002
Hollow mills and box tools	1/32	0.011
	1/16	0.010
	1/8	0.008
	1/4	0.006
Knurl: Turret on		0.025
Turret off		0.030
Top or swing		0.007 to 0.014
Recessing tools		0.0015 to 0.003
Cut off tools: Rough work		0.0025 to 0.0055
Finish work		0.002 to 0.004

tion of the composition, are proportional to each other, and that the energy used in milling is roughly proportional to the other two values.

Practice

It is customary to run ordinary free-turning brass rod at the maximum spindle speed of the screw machine, which varies with the size, type, and make. However, surface speed must take into account the number and kind of the operations; for instance, if deep drilling is required, the surface speed is often controlled by the speed at which it is possible to drill. The table gives what is considered good practice, although tolerances, finish, and other factors must be considered in adapting the figures to a specific job.

Drilling — Either carbon steel or high speed drills are used, tempered soft enough to distort rather than break the drill if it sticks. High speed steel drills are now generally recognized as being superior to carbon steel for automatic screw machine work. The drills are rotated opposite to the work when drilling deep holes in order to remove chips from the point. A depth of five times the diameter may be drilled without removing the drill to clear the chips. By the use of half round drills, however, the above figure can be exceeded by 50%. The flutes are buffed to prevent the brass from piling up. Grinding off the sharp angles of the cutting edges (that is, reducing the rake angle) will permit the use of heavy feeds without "hogging in." A drill ground in this manner, however, will throw more burr than one which is ground in the standard manner. If drills break, reduce the feed rather than the speed.

Turning and Forming — The width and type of the forming tool must be considered when using the figures in the first table. Brasses containing large amounts of copper should be machined with tools having greater clearance and rake angles than those used for ordinary free-turning brass rod.

Tap and Die Operations — With multiple spindle machines, it is considered good practice to use $\frac{1}{5}$ to $\frac{1}{3}$ of the speed of the machine.

Knurling — Coarse knurls must be made at a slower speed than fine knurls.

Influence of Metal

Lead in the alloy produces a short chip; the higher the lead content of brass, the greater the tendency of the chips to break up into small particles. For this reason, *(Cont. on p. 62)*

PROPERTIES OF BRASS AND BRONZE RODS (DRILL TEMPER)

Trade Names	Composition			Tensile Properties			Hardness		Relative Machinability	Cold Heading Property	Cold Bending Property
	Lead	Tin	Zinc	Ultimate Strength	Yield Point	Elongation in 2 in.	Rockwell F	Rockwell B			
Free-turning rod	3.0		35	45 to 65,000	25 to 55,000	10 to 30	90 to 105	57.5 to 82	100	Poor	Fair
Copper				35 to 50,000	25 to 40,000	20 to 35	70 to 80	23.0 to 40	20	Excellent	Excellent
Leaded copper	1.5			25 to 50,000	25 to 40,000	20 to 35	70 to 80	23.0 to 40	80	Good	Good
Phosphor bronze		5.0		55 to 85,000	30 to 60,000	10 to 20	95 to 115	67.5 to 100	20	Good	Good
Leaded phosphor bronze	1.0	5.0		55 to 85,000	50 to 60,000	10 to 20	95 to 115	67.5 to 100	50	Fair	Fair
Forging rod	2.0		38	50 to 65,000	25 to 55,000	10 to 30	95 to 110	67.5 to 93.5	80	Poor	Fair
	3.0		37	50 to 65,000	25 to 55,000	10 to 30	95 to 110	67.5 to 93.5	90	Poor	Fair
			38	45 to 65,000	25 to 55,000	15 to 35	90 to 105	57.5 to 82	35	Good	Good
	0.5		37.5	45 to 65,000	25 to 55,000	15 to 35	90 to 105	57.5 to 82	55	Fair	Good
	1.0		37	45 to 65,000	25 to 55,000	10 to 30	90 to 105	57.5 to 82	80	Fair	Fair
	2.0		36	45 to 65,000	25 to 55,000	10 to 30	90 to 105	57.5 to 82	90	Poor	Fair
Rivet wire			30 to 35	45 to 65,000	25 to 50,000	25 to 50	90 to 105	57.5 to 82	35	Excellent	Excellent
	0.2		30 to 35	45 to 65,000	25 to 50,000	25 to 50	90 to 105	57.5 to 82	40	Excellent	Excellent
High brass pipe	0.5		30 to 35	45 to 65,000	25 to 50,000	25 to 50	90 to 105	57.5 to 82	55	Good	Good
Semi-leaded rod	1.0		30 to 35	45 to 65,000	25 to 50,000	25 to 45	90 to 105	57.5 to 82	70	Fair	Good
Muntz metal			40	50 to 65,000	25 to 55,000	15 to 35	95 to 110	67.5 to 93.5	35	Good	Good
Chamet		0.75	39.25	55 to 70,000	25 to 55,000	15 to 35	95 to 110	67.5 to 93.5	30	Good	Good
Leaded chamet	0.75	0.75	38.5	55 to 70,000	25 to 55,000	15 to 35	95 to 110	67.5 to 93.5	65	Fair	Fair
Commercial bronze			10	45 to 60,000	30 to 45,000	20 to 35	75 to 95	31.0 to 69.5	25	Excellent	Excellent
Leaded commercial bronze	1.0		9.5	45 to 60,000	30 to 45,000	20 to 35	75 to 95	31.0 to 69.5	50	Good	Good
	2.0		9	45 to 60,000	30 to 45,000	20 to 35	75 to 95	31.0 to 69.5	90	Fair	Good
	4.0	4.0	4	45 to 60,000	30 to 45,000	20 to 35	75 to 95	31.0 to 69.5	100	Poor	Fair

FABRICATION OF 18-8

(and 15-10 in England)

by J. A. McWilliam
Metallurgist
Thos. Firth & John Brown, Ltd.
Sheffield, England

IT IS UNNECESSARY to rehearse again the discovery of stainless steel and the development of the other more highly resistant chromium and chromium-nickel alloys now proving so valuable to industry. One point is perhaps worth emphasis to an American audience — English firms have vigorously pushed other alloys as well as the 18-8 which seems to dominate your technical literature. Notable among these are the 15 to 16% Cr, 10 to 11% Ni, low carbon alloys, which have good physical properties, and are very much like the 18-8 in corrosion resistance. The steel containing 13% chromium and 13% nickel is very soft, but somewhat less resistant to corrosion than the 18-8 steel. The addition of molybdenum gives increased resistance to certain acids.

A comparison of the mechanical properties of low carbon stainless steel and the two favored chromium-nickel steels is given in the table at the top of the next page.

This is no place for a discussion of the trouble known as intercrystalline corrosion, or, as it is sometimes called, weld decay, or disintegration. Photomicrographs show the segregation of a constituent, generally thought to be carbide, along the grain boundaries after long heating at certain temperatures. This makes the boundaries much less resistant to corrosion than the bodies of the crystals.

To get over this trouble, the first thing one would naturally try is to lower the carbon in the steel. Some people maintain that an 18-8 steel with carbon 0.08% maximum is immune from this trouble, but our experience goes to show that mere lowering of the carbon is not sufficient.

The range of temperature over which this segregation of carbide is liable to occur is from about 850 to 1650° F. This means that during welding there is always a belt of metal on either side of the weld which has been heated up to the bad range. With the plain 18-8 steels, this means that after welding it is necessary to heat up to 2100° F. and cool rapidly in order to insure that the metal is in its best state to resist corrosion.

This heat treatment was inconvenient and many times impossible. The addition of tungsten has meant that the steel can be welded and

COMPARISON OF MARTENSITIC AND AUSTENITIC ALLOYS

Material	Analysis of Sample					Condition	Tensile Properties			
	C	Mn	Si	Cr	Ni		Yield lb. per sq. in.	Ultimate lb. per sq. in.	Elongation per cent	Reduction of Area
Martensitic low carbon stainless steel	0.11	0.19	0.21	14.8	0.23	As rolled	87,000	141,000	12.0	29.5
						Air hardened and tempered	54,000	67,500	29.6	70.2
Austenitic 15-11	0.13	0.25	0.30	15.2	11.1	Rolled	55,000	97,000	41.0	39.0
						Softened at 2100°F.	38,000	82,500	51.8	50.0
Austenitic 18-8	0.12	0.24	0.32	18.1	7.9	Rolled	61,500	112,000	39.5	39.0
						Softened at 2100°F.	38,500	96,500	48.0	46.0

put into service without further heat treatment. There are still some conditions so exacting that heat treatment after welding is necessary even with the steel containing tungsten. In such cases the addition of titanium as well as tungsten has provided a steel for safe use in the as-welded condition.

The small additions mentioned, when added to the 18-8 steels, do not have much effect on the mechanical properties.

Before passing to the fabrication methods, it may be interesting for some to know that we in Sheffield are able to furnish ½-in. plate up to 20 ft. long and 7 ft. 6 in. wide. We have also made a hollow forging from a 20-ton stainless steel ingot. This was, after machining, a cylinder 20 ft. long by 30 in. outside diameter, and was supplied to a Canadian pulp and paper plant as a drying roll. Solid drawn tube ("seamless") is produced in England from 9 in. diameter down to hypodermic needles.

Hot Working and Welding

Hot working of the 18-8 and 15-10 alloys should be done between 2100 and 1740° F. After hot working it is advisable to soften by reheating to 2100° F. and rapidly cooling preferably by water quenching.

These austenitic steels lend themselves to cold work, and may be reduced 25 to 30% in thickness or diameter, raising the Brinell hardness from 160 to over 400, and still retaining remarkable toughness. Cold pressing can be done readily to a depth of one-third of the diameter without intermediate softening.

Softening leaves a scale on the material which can most readily be removed by descaling in a bath containing half and half, by volume, of water and hydrochloric acid, to which has been added 5% of nitric acid and ¼% of a restrainer.

Electric arc welding is suitable for the heavier work and even down to as thin as 0.070 in. The electrode must be one which deposits metal of the same composition as the sheet being welded. The arc should be kept short and it is usually found preferable to hold the electrode vertical. Owing to the low thermal and electrical conductivity of the material, the electrodes get so hot one should use only about one-third of an electrode and then, allowing it to cool, continue with a new electrode and so on. For welding ⅛-in. and thinner, an electrode two gages thicker than the sheet being welded is advisable. In filling a deep vee, a light electrode should be used at the bottom and a heavier rod for the upper layers; each deposit should be well scratched with a wire brush before the next layer is welded to insure that no slag or scale gets trapped.

Good welds can be produced by the electric seam welder, a somewhat lower current than with mild steel being required.

In oxy-acetylene welding, correct flame control is of first importance. If excess acetylene is used, the steel in the weld is liable to contain increased carbon, which would cause the steel to be less ductile and less resistant to corrosion. With excess oxygen the metal may be burned and an unsound weld result. A good method of getting a correct flame is to start with excess acetylene and cut it down till there is only a slight haze around the inner cone. The flame should be checked periodically as the blow-pipe warms up. The tip should be held close to the sheet so that the end of the inner cone is touching. The filler wire should also be fed close to

the inner cone. In certain cases a flux is desirable; it should be mixed with water and applied as a thin paste, particularly where smooth penetration is required on thin sheets. Oxy-acetylene butt welding may be done on sheets down to 0.030 in.; for thinner use edge welding.

There is no special difficulty in welding with atomic hydrogen.

In welding the 18-8 steels, it should be remembered that they have a higher coefficient of expansion and lower thermal conductivity than ordinary steels. All methods of welding produce a discoloration of the surface, which, if immunity from rust is required, must be removed either by the descaling solution mentioned before, or by mechanical means, such as grinding.

Soft soldering does not present any great difficulty, various fluxes having been found satisfactory for this. One which works well is a saturated solution of zinc chloride in 50% hydrochloric acid. Care should be taken after soldering to wash not only the joint but also the adjacent sheet, as particles of flux are liable to produce rust spots. Seaming can be done quite readily and in double seamed and soldered joints the parts to be folded should be tinned before seaming.

Hard soldering with silver solder produces a satisfactory joint, using a flux containing equal parts of potassium fluoride and boracic acid. Brazing, although possible, is not particularly recommended.

Riveting and Machining

Cold riveting is used on thin gage sheets, and hot riveting on plate work. We find that hydraulic riveting is preferable to pneumatic riveting in hot work, and a full normal hemispherical head should not be aimed at owing to the high strength of the material.

Machining of these steels, although more difficult than the cutting of mild steel, does not present any great difficulties when done in the proper manner. The general principle is to use a sharper nosed tool and to finish-machine at a high speed. Machines and tools should be rigid and free from backlash, the tools being made from a really good high speed steel. A lubricant should be used wherever possible, particularly as these steels have a low thermal conductivity and high coefficient of expansion. Recom-

Machining 18-8 Requires Sharp Nosed Tools of First Quality, High Speed Steel and Machinery That Is Free From Chatter and Backlash

Photo by Lewis W. Hine, Hastings on Hudson

RECOMMENDATIONS FOR MACHINING 18-8

	Light Work		Heavy Work	
	Rough Turning	Finish Turning	Rough Turning	Finish Turning
Cutting speed, ft. per min.	30 to 50	80 to 100	45	40 to 60
Depth of cut, inches	1/16	0.002 to 0.003	3/16	0.004
Feed, inches	1/36	1/48	1/40 to 1/16	1/48 to 1/80
Cutting angles:				
Front rake	10° to 20°	15° to 20°	10° to 20°	15° to 20°
Side rake	10° to 15°	0° to 5°	10° to 15°	0° to 5°
Front clearance	5° to 10°	5° to 10°	5° to 10°	5° to 10°
Side clearance	5° to 10°	5° to 10°	5° to 10°	5° to 10°

mended angles and speeds are given in the table above.

If difficulty is experienced in drilling, the cutting lips should be ground with rather more back clearance than usual and the point of the drill should be thinned. In tapping more allowance should be made for swelling. The tables give suggested drilling and tapping conditions.

Milling can be done at speeds of 50 to 60 ft. per min. for average conditions, the cutter having from 10° to 15° undercut. For sawing, high speed steel hacksaw blades have been found necessary working at about 90 to 100 strokes per min.

The field of application for chromium-nickel steels is very wide and in the manufacture of chemical equipment has reached a high stage of development. Large portions of nitric acid plants in different parts of the world are made from these steels. Tanks and drums for the storage and transport of acid are in extensive use. Addition of 2½% molybdenum to the 18-8 steel gives a steel resistant to strong acetic acid, one of the most difficult acids to handle. This composition is also of particular value in parts of sulphite digesters for treating wood pulp.

Large amounts of British 18-8 steel are being used in Canada and throughout the empire in the manufacture of kitchen and cafeteria and hospital equipment, and in London, where the atmospheric conditions may be said to be severe, numbers of shop fronts have been made of this material during the last few years.

Among many applications in the dairy industry may be mentioned road and rail transport tanks up to 3000 gal. capacity, and brine-jacketed storage vats up to 2000 gal. In the preparation of almost every kind of food stuff these steels find successful use. Foods cooked or stored in them are entirely free from metallic flavor. The equipment is also easily cleaned.

This elimination of any metallic contamination is of the greatest importance in making dye vats and machines for the textile industry.

PROPER CONDITIONS FOR DRILLING AND TAPPING

Drilling			Tapping		
Diameter of Drill	Revolutions per min.	Feed per Revolution	Nominal Size Tap (Whitworth)	Standard Tapping Hole for Carbon Steel	Recommended Tapping Hole for Austenitic Steel
1/16 in.	1500	0.001 in.			
1/8 in.	800	0.0025 in.	1/4 in.	0.188 in.	0.203 in.
1/4 in.	400	0.005 in.	3/8 in.	0.297 in.	0.312 in.
1/2 in.	225	0.0075 in.	1/2 in.	0.406 in.	0.413 in.
13/16 in.	180	0.010 in.	3/4 in.	0.625 in.	0.641 in.
1 in.	150	0.011 in.	1 in.	0.844 in.	0.859 in.

Discoloration of dye from the metal containers has been shown to be less with the 18-8 steel than with any other available metal.

We have recently cast Pelton wheel buckets and turbine casings in stainless steel weighing over 10 tons. Wear on pump rods, spindles and impellors is noticeably less than with ordinary steel or bronze. It is important that the use of graphite packing be avoided as far as possible, as it is liable to cause electrolytic action.

The chromium-nickel-tungsten heat resisting steels find a most important application in aero work, namely exhaust valves and manifolds. One of these steels is non-scaling up to 1800° F. and at 1475° F. has a strength about six times that of mild steel at the same temperature. The supermarine Rolls-Royce engine on the Schneider Cup winner, as well as having such valves, had many parts of stainless.

This ability to resist, simultaneously, stresses, high temperature oxidation and severe chemical corrosion, is of course one of the reasons for the large use of seamless 18-8 tubes for petroleum refinery equipment.

SUPPRESSION OF BANDING

in SAE 3100

gear steels

by Harold L. Geiger
Metallurgist
Wisconsin Steel Works
South Chicago, Ill.

DEVELOPMENT of alloy steels for the automotive and other industries has presented to the metallurgist numerous problems, most of which have involved extensive studies of heat treatment, microstructure, and physical properties, whose results have led to a greatly improved product. Some of the parts common to the automotive industry which have profited by this study are crankshafts, countershafts, drive shafts, transmission spline shafts, axles and gears of all types.

Metallurgical problems in connection with gearing have probably given the greatest concern to steel users, as it is in gears that the greatest amount of distortion occurs in quenching and it is a part where least distortion is desirable. Tooth strength and resistance to wear are the other two very important conditions to satisfy.

Distortion in quenching has been minimized partly by proper forging practice, by quenching presses, and the use of single-quench steels. Proper strength of the teeth has been achieved by choosing the right steel and heat treatment. Resistance to wear has resolved itself into the question of "to carburize or not to carburize," and, as a result, two lines of gear metallurgy have developed. One group of steel users finds best results in a 0.40% carbon heat treated alloy steel, while the second group prefers a 0.15 to 0.20% carbon alloy carburizing steel.

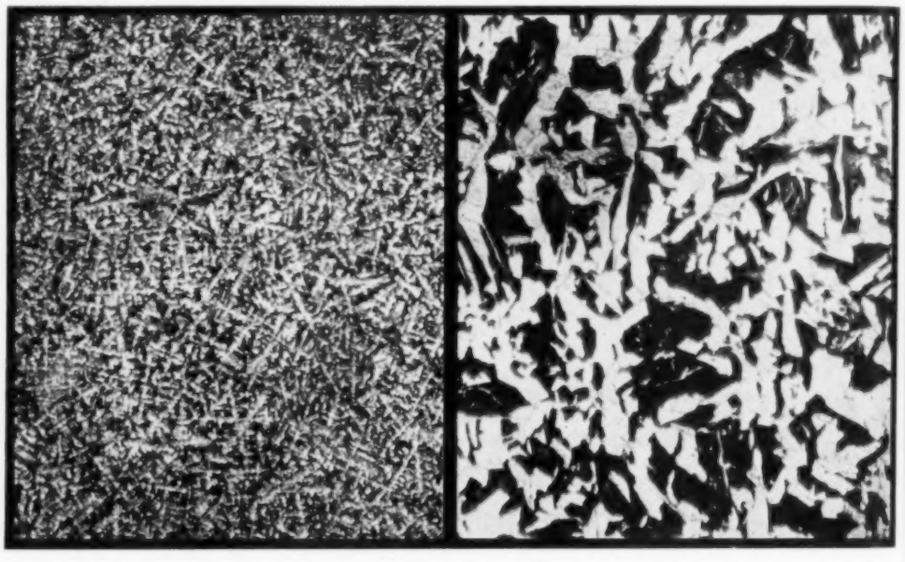
In this second group of carburizing alloys the nickel steels have found an outstanding place. Those most commonly used are S.A.E. specifications 3115, 3120, 2315, 2512, 4615, and the steel containing 3½% nickel and 0.20% molybdenum. All of these exhibit good wearing qualities, have very tough cores and high tooth strength, the specific values depending on the amount of nickel present and the heat treatment given them.

In this group of steels proper heat treatment is an important factor in obtaining maximum core strength and uniform structure, principally because it is the nature of these steels to form dendrites in the ingot on freezing. This typical structure of the S.A.E. 3100 series steels when cast is shown in the first view, a macro at two-thirds real size, after deep etching with hydrochloric acid. Such dendrites, when elongated by rolling and forging, tend to form bands in the microstructure. This tendency on the part

of *all* alloy steels (and particularly nickel steels) has aroused the interest of investigators from time to time, resulting in bits of published data.

Keshian is the principal authority. His work was published in *Transactions*, A.S.S.T., March 1930. He studied the mechanical properties of steels with large dendrites and compared them with those of steels with very small or microscopic dendrites, and attempted to determine whether these features developed by the deep-etch test in fine steels had any measurable significance as to the intended use. Nearly all of the tests showed no difference in properties of the small and the large dendritic, while in some cases the steels with the larger dendrites showed superior qualities. Difficulty in eliminating this structure is well illustrated in a recent paper in *Transactions* (Nov. 1931) by Sauveur and Reed in which the persistence of dendrites in very pure nickel-iron alloys to retain the natural "as cast" structure after annealing is shown. Ingots having as little as 0.04% carbon (9.8% Ni) exhibited a pronounced dendritic structure in the cast and annealed condition, from which they inferred that nickel causes the observed segregation.

McKnight suggests in *Transactions*, Vol. 18 (1930), page 12, that normalizing at 1800 to 2000° F. is sometimes effective in minimizing this banding in nickel alloy steel forgings.



Dendrites, Typical of Ingot Structure of Nickel-Chromium Gear Steels. Two-thirds normal, deeply etched with HCl

Structure, in Line With Rolling, of 1.25-In. Slab of S.A.E. 3115, As Rolled. All microphotographs at 100 diameters

Banding is Inherent

The present author has from time to time had the occasion to examine alloy carburizing steels from various sources, made in both the acid and basic open hearth and by the basic electric process. Almost invariably, upon annealing these samples, a ferrite banding appeared in the core. Further study of this banded structure resulted in the following conclusions:

1. That banding in alloy carburizing steels originates in practically all cases from the elongation of the natural "as cast" dendrites during rolling and forging.

2. That such banding is a result of a natural crystalline formation, and not due to any fault in processing.

3. That ferrite banding in alloy steels is not as a rule associated with inclusions, and thus differs from ferrite banding in plain carbon steels, where it is usually found enveloping inclusions.

4. That practically all alloy steels freeze in the form of dendrites which may vary from microscopic size up to several inches in length.

5. That due to this natural tendency to form dendrites, all low carbon alloy carburizing steels should show ferrite banding when elongated by forging or rolling.

6. Pouring temperature, analysis of the metal, rate of freezing, and rate of teeming influence the extent of dendritic growth.

7. That several rolling mill reheatings and bar conversions followed by forging of the steel will not break up this structure.

With the relation of the processing to banding fairly well established, the effect of various

heat treatments on this banded structure was investigated. We hoped to eliminate the bands completely or to complete the carbon migration throughout the quenched specimen. Accomplishing either end would insure more uniform core structures for alloy carburizing gears.

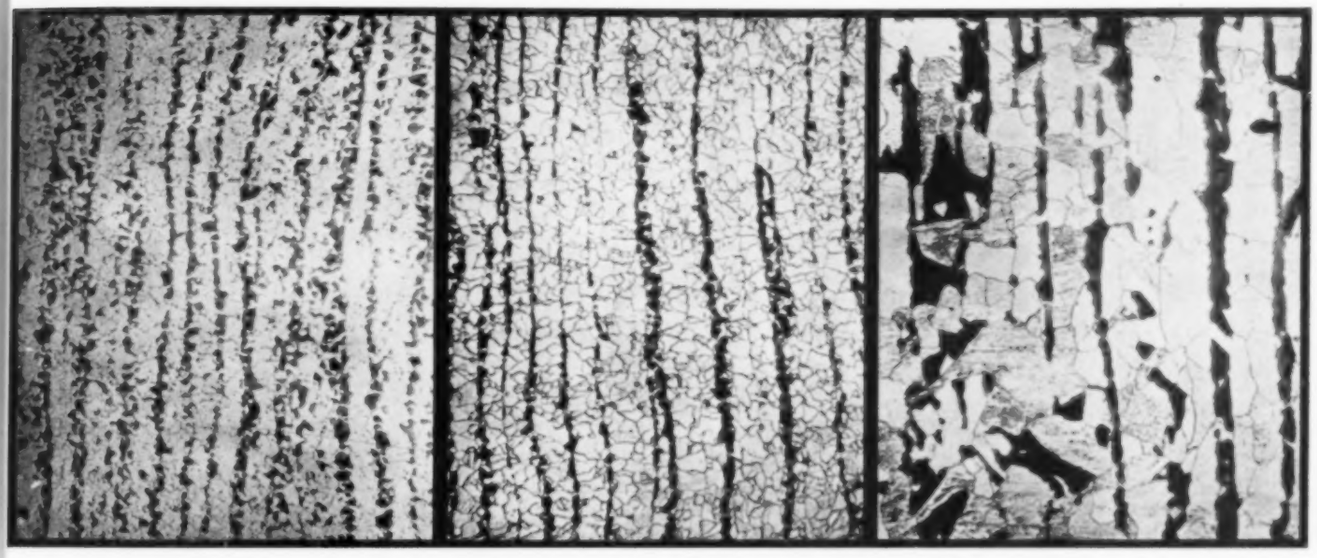
Bands Survive Annealing

Specimens used for this work were cut from a flat, 1¼ in. thick, rolled from a heat of S.A.E. 3115 steel of the following analysis: Carbon 0.16%, manganese 0.46, phosphorus 0.017, sulphur 0.023, silicon 0.18, nickel 1.23, chromium 0.63%. Samples were 1 in. square and ½ in. thick, cut with the large face parallel to the minor axis of the flat in the direction of rolling. These samples were polished and then etched with 2% nital. An average "as rolled" structure is shown in the right hand photomicrograph on page 38. There is a slight indication of banding in this photograph, but hardly enough to call the structure banded.

Three groups of specimens were annealed at different temperatures — one group for 1 hr. at 1525° F., another group for 1 hr. at 1650° F., and the third group for 6 hr. at 1750° F. — but all specimens were cooled at the same rate of 200° F. per hr.

Resulting structures were all banded. The central view on this page is representative of the samples after annealing at 1650° F. The smaller grain, but banded, is representative of the pieces annealed at 1525° F., and a much larger grain results from the long heat treatment at 1750° F. This change in grain size was entirely according to expectation. The important point is that a commercial anneal does not break up the structure.

Samples of the two groups first mentioned were then given a variety of treatments, as follows: One piece was normalized at 2100° F. for 1 hr.; another was normalized at 1650° F. for 1 hr.; another was heated 1 hr. at 1650° and quenched in water; another after such a hardening was drawn at 800° F. for 45 min. and still another drawn at 1200° F. for 45 min.



Rolled Nickel-Chromium Steel After Annealing and Cooling at 200° F. per Hour

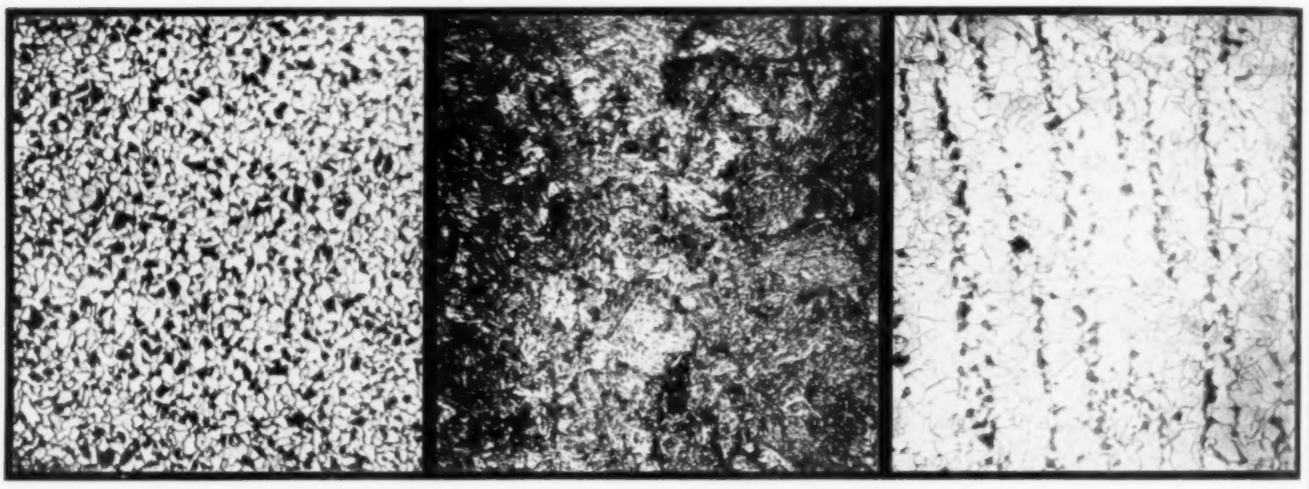
Annealed 1 hr. at 1525° F. *Annealed 1 hr. at 1650° F.* *Annealed 6 hr. at 1750° F.*

Microstructures were practically the same in both groups, except that the refining effects on one group of the preliminary annealing at 1525° F. were evident. (Microstructures of the group annealed at 1650° F. are used on page 40 to illustrate the heat treating effects.) The left hand view represents the effects of normalizing at 1650. This sample was cooled black in 10 min., which was insufficient time for the carbon to seek areas of lower nickel content. An even distribution of the carbides resulted, with an apparent elimination of the banding. The tendency was still there, as will be shown.

Normalizing at 2100° coarsened the grain enormously, but also eliminated banding of ferrite and pearlite.

A uniform martensitic structure was obtained by the water quench from 1650° F. Drawing at 800° F. to 1200° F. after this water quench caused no evidence of a recurrence of the bands (center view at 100 diameters, etched with 2% nital).

After the above heat treatments, the samples having no evidence of banding were then given a re-anneal for 1 hr. at 1650° F. and cooled at the rate of 200° F. per hr. All of these samples, when repolished and etched, showed a structure as represented in the right hand figure, indicating that the fundamental structure that is responsible for banding had not been broken up.



Condition of 3115 Steel, Annealed at 1650° F., After Further Treatment

Normalized 1 hr. at 1650° F. | *Quenched from 1650 and drawn at 800° F.* | *Quenched and drawn, and annealed 1 hr. at 1650° F.*

Suppress by Rapid Cooling

It appears that a slightly higher concentration of nickel dissolved in the ferrite (due to differential freezing of the dendritic crystal) will have a tendency, on very slow cooling, to reject the carbon to areas of slightly lower nickel concentration, producing the banding effect, and that the following conclusions may be drawn:

1. The fundamental structure responsible for banding is not broken up by any of the ordinary practical heat treating methods, as indicated by its recurrence after annealing. The nickel migrates very slowly.

2. Under ordinary practical heat treating methods, carbon migration is complete above the Ac_3 point;

(*a*) To obtain complete carbon migration, sufficient soaking time above the Ac_3 point is necessary;

(*b*) Quenching from above the critical point after proper heating retains the carbon as martensite in an evenly distributed condition; and

(*c*) Drawing to as high as 1200° F. shows no indication of a reappearance of the banded structure of the annealed steel.

3. Normalizing (air cooling) leaves the carbon more evenly distributed and therefore it is more readily absorbed on reheating for quenching.

4. The resulting even carbon distribution, after normalizing, indicates that there is only a slight nickel differential in the bands and the area between the bands.

These facts emphasize the necessity for proper heat treatment. With this in mind, the heat treater may control his heating practice on alloy carburizing steels so as to obtain the uniformity of structure which is essential to a tough core and maximum strength of gear teeth.

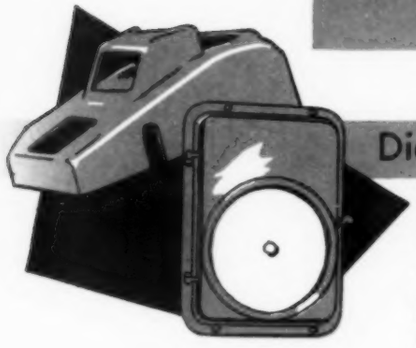
Re-Design Gains Recruits

On one point, at least, the depression has been good for us. It has shown that, unless re-designed, thousands of products will not fit today's, let alone tomorrow's market. . . Product re-design has gained many recruits, and found customers' quick cash approval.

In my work with manufacturers, I have re-designed products as widely different as Street Cars and Coffee Pots . . . and I have always found that Alcoa Aluminum is at once plastic to the needs of design . . . possesses the tensile strength of steel, yet is only one-third as heavy. It can be used in all forms known to the metal workers' art.

Lauds Gould

ALCOA



Die Cast, they cost less, are lighter, stronger

For the thin-walled case that must rigidly protect the sensitive actuating elements of the accurate recording pressure gauge . . . a Die Casting of Alcoa Aluminum. A Die Casting also for the Adding Machine Case, because when made of old-fashioned sheet metal it was springy . . . required felt lining to make it sound-proof.

Keeping Things Cold . . . Keeping Things Hot

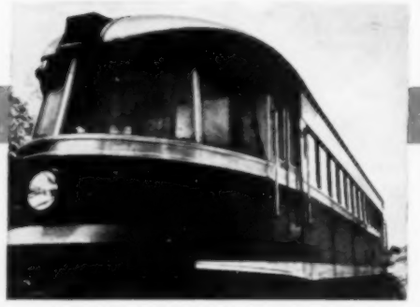
Alcoa Aluminum exhibits the practical paradox . . . made into millions of Mechanical Refrigerator Ice Trays, it aids quick freezing . . . because of its high thermal conductivity. And paradoxically, the low emissivity of Alcoa Aluminum assures piping hot coffee in the recently designed Early American Drip Coffee Pot.

Re-Design cut dead-weight 50%

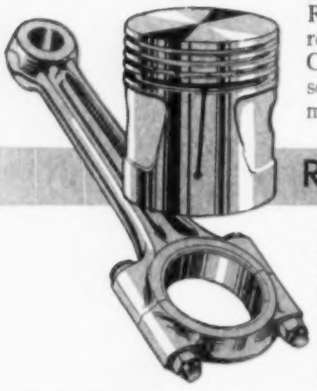
And, more important . . . increased the pay-load of these Coal Dump Trucks by 50%. Now the fixed capacity of each body is 17 cubic yards—and side extensions increase it still further to 24 cubic yards. A case of Product Re-Design, using Alcoa Aluminum with first emphasis on its lightness and strength.

ALCOA ALUMINUM

40% less K.W. energy drives it over 60 m.p.h.



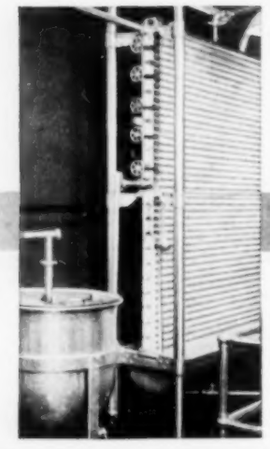
A fine example of using the extreme lightness and strength of Alcoa Aluminum in functional Re-Design. Never were dead-weight and air-resistance so drastically reduced in Interurban Car Design. Seldom were operating costs cut so deeply. Material cost? . . . amortized in 39 months by savings on K. W. energy alone.



Re-Designed for closer fit, longer life, greater power

Alcoa Aluminum carries off heat many times faster and is only ⅓ as heavy as old-fashioned metals. The majority of automobiles have Pistons or Connecting Rods made of the alloys of Alcoa Aluminum. These reciprocating parts take 3000 sledge hammer blows every running minute . . . provide greater speed, more pulling power, longer life, less carbon and vibration.

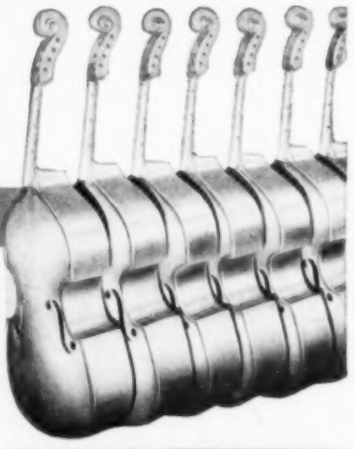
Buildings . . . with Walls of Alcoa Aluminum



The light, strong, corrosion-resisting Alcoa Aluminum alloys convert 8 to 10 inches of wall thickness into income earning space. . . . That's real *functional* Re-Design. Standardized wall sections shop fabricated . . . erected in a minimum of time. Yet these walls . . . only 3½ inches in total thickness . . . have an insulation value equal to masonry walls 32 inches thick.

Sanitary . . . Aluminum cools milk at lower cost

Cooling pasteurized milk is another example of the important jobs that Alcoa Aluminum does. Being non-toxic, Alcoa Aluminum doesn't impart a metallic taste to this vital food product . . . doesn't destroy its delicate vitamin C content. The aluminum tubes are easily fabricated . . . and easily cleaned.



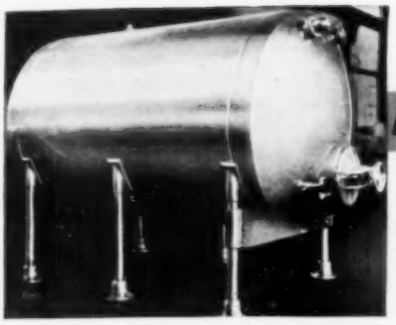
Re-Creating the "Strad" . . . the "Cremona"

Artists . . . accustomed to wooden instruments . . . played the aluminum ones and were amazed at their tonal qualities and responsiveness. Instruments . . . impervious to weather changes . . . proof against warping, etc., . . . are welded at the joints so that the entire ensemble is a single unit. Back and front panels, neck and key sections are stamped from sheet . . . scroll is composed of two thin die-castings. . . Price? . . . as low as for any good instrument.

● **Before you design a new product, or re-design an old one, consider the advantages of Alcoa Aluminum. Parts made of Alcoa Aluminum and its light, strong alloys can be readily forged, cast, welded, joined, machined and finished. Cost is low, on a par with other metals not having qualifications of Alcoa Aluminum.**

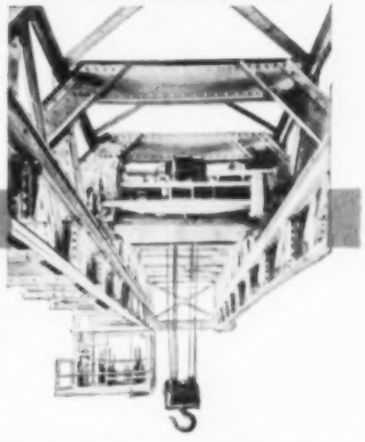
ALCOA

ALCOA



Milk Tank . . . Re-Designed . . . low cost, long life

Holds 2000 gallons and weighs only half as much as common construction. Outside insulation provided by Alcoa Aluminum Foil which weighs only 1/50th as much as the lightest common insulator. No glass inner lining, because Alcoa Aluminum doesn't corrode, or impart metallic taste to any food.



Builds 10-ton Crane . . . that weighs 23 tons less

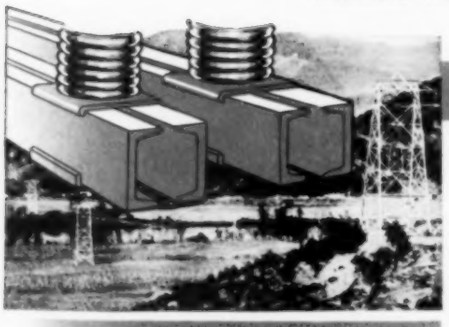
Without previous experience in using the light, strong alloys of Alcoa Aluminum . . . this Ohio manufacturer stepped out . . . built a *new* truss type travelling crane. Built of strong aluminum alloy structural shapes and having an aluminized trolley, it cut weight 23 tons . . . reduced size of bridge drive motors from 45 to 19 h. p. . . . cut cost of structural supports.

Puts Milk under Tamper-Proof Alcoa Aluminum Seal

Covering the entire pouring lip of the bottle, these Alcoa Aluminum Foil Seals insure that . . . no one can meddle with the cap without leaving tell-tale evidence . . . no germs, dust or foreign matter can get IN . . . and no milk can get OUT. It's a *new* milk packaging idea . . . cheap enough to use on *all* grades of milk.

Re-Design . . . couples Beauty and Brute Strength

In Aluminum Chairs . . . beauty is a joy forever. . . The frames are welded into one continuous piece of metal. Dowels and joints are eliminated. A rigorous work-out, in club, office, convention hall, hotel, restaurant or home, never leaves an Alcoa Aluminum Chair in a weakened condition. These chairs won't loosen or wobble, squeak or splinter.



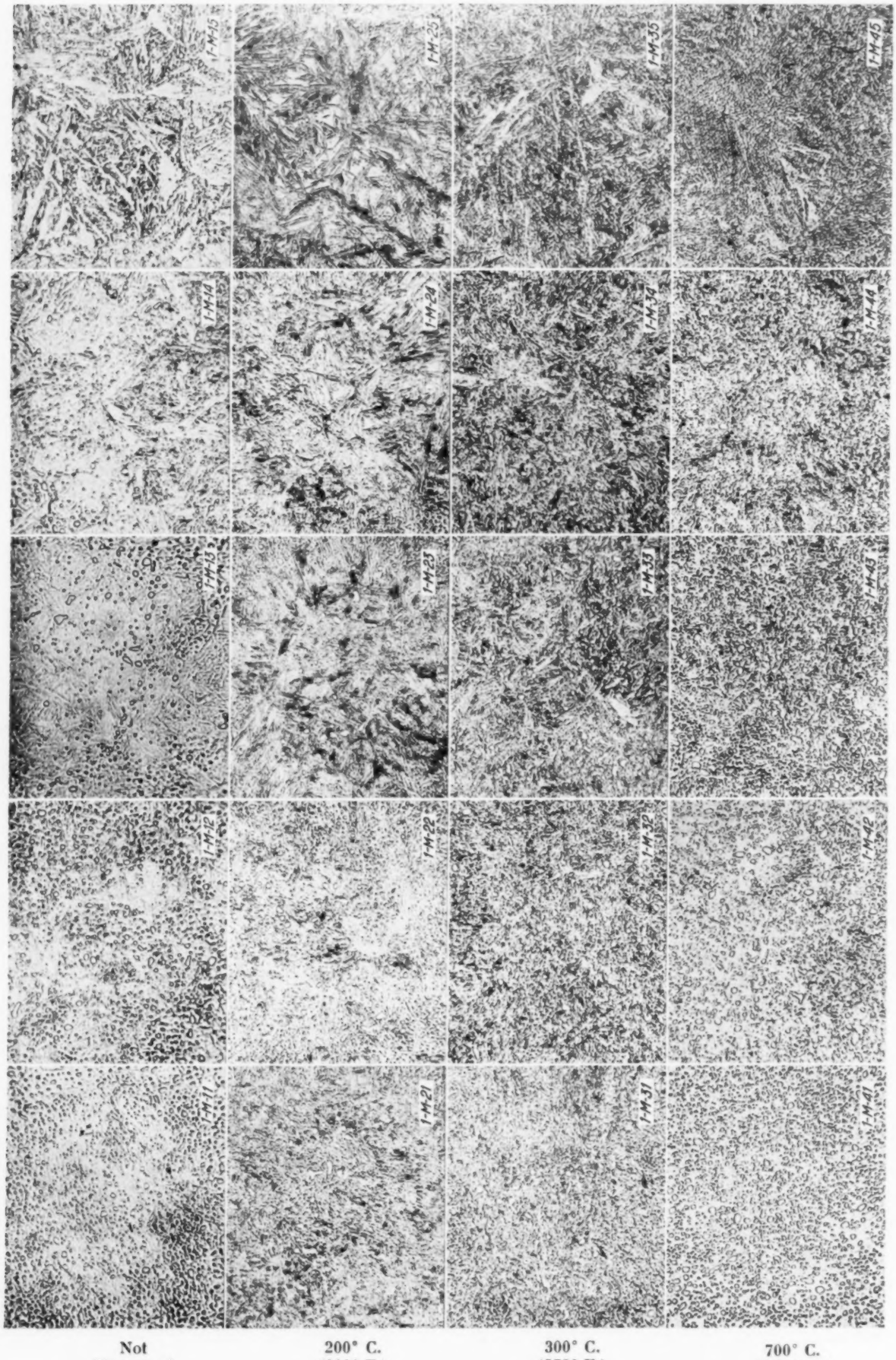
The hollow-square goes to work . . electrically

Re-Design with Alcoa Aluminum scores again! . . . this time with Channeluminum conductor consisting of two Alcoa Aluminum Channels available in lengths up to 90 feet. Used with either D. C. or A. C. current . . . need fewer supports because like all other forms of aluminum conductor, they are, for equal capacity, at least 52% lighter than busses made of other commonly used metals. Erected flange to flange, as a hollow square, they provide internal ventilation.

Large warehouse stocks in principal cities enable us to fill your orders quickly. Ask for the name of your nearest distributor. If you want information on how to use, form, or handle Alcoa Aluminum in any manner, please write ALUMINUM COMPANY *of* AMERICA; 2501 A Oliver Building, PITTSBURGH, PENNSYLVANIA.

ALUMINUM

Quenched and Tempered Martensite in 1% Carbon Steel



Martensite Coarsens, and Excess Carbide Dissolves, as Quenching Temperature Increases

Not Tempered | 200° C. (392° F.) | 300° C. (572° F.) | 700° C. (1292° F.)

Micros (at 1000 Diameters, Etched With 1% Nital) by SKF Research Laboratory. Part of a Series Described September, 1931

CORRESPONDENCE

and

foreign letters

PARIS, *France* — We have pointed out in the last letter the valuable guide posts for researches on alloys provided by our knowledge of the constituents and the granular structure. Although this knowledge sheds considerable light upon the nature and the properties of metallic materials, many points remain dark, and many questions unanswered: Why are there similarities or differences between some alloys? Where does the tendency to form solid solutions or definite compounds come from? Why are some metals and some solid solutions more malleable than others, or harder, or more brittle? How can variations and some exceptional values of chemical or magnetic properties of solid solutions be explained? Upon what does the hardness of definite compounds depend?

Classical and Atomistic Metallography

Satisfactory answers are now being given to these questions by a new investigational method — X-ray spectrography — and by the new conceptions of the constitution of matter held by modern physicists.

As we said previously, the microscopical and thermo-physical studies informed us only about the structural units — that is, the internal architecture — and at the same time they correlated this structure with many physical properties. We may now possess a more complete and intimate view; we see three degrees, three regular orders, each of them contributing to the total knowledge of metallic properties:

1. A structure visible to the eye or to the microscope. This is the macrostructure or microstructure, of which the grain is the individual element. Its study is the subject matter of microscopical metallography. Such a structure, being visible, belongs to the sphere of our senses.

2. A second structure, incomparably finer, and invisible even under the highest magnification, is accessible to X-ray spectrography and comprises the crystalline structure of the grain. Its structural element is the atom, simple or complex. This structure is but indirectly accessible, and belongs to the sphere of the intellect.

3. The most intimate structure is postulated by the hypotheses of modern physics. It is not accessible to direct observation and experimentation, but it can be verified in many of its consequences. This is the atomic construction; its elements are the core and the electrons. It belongs also to the intellectual sphere.

CORRESPONDENCE

The last two structures, the crystalline and the atomic, are closely related because the dimensions of the atom are measured by the mesh of the crystalline lattice.

Let us make the following comparison: Classical metallography, by virtue of the equilibrium diagram and a knowledge of the microscopical structure, showed us where the fields that may be cultivated were to be found, but did not guarantee the harvest nor indicate the most fertile areas. It prevented useless experiments by bounding the areas to be searched. On the other hand, the new metallography will be able to indicate, in advance, the proper directions to take and will permit a prediction as to the result.

Thus we observe a new metallography, full of promise, appearing by the side of classical metallography. We may call it atomistic metallography.

While classical metallography is of daily use, rendering great services by explaining *a posteriori* most of the phenomena and variations of the properties observed in alloys and (arranging them in the form of rules) allowing us to use them judiciously, the new atomistic metallography, on the other hand, goes to the very nature of the constituents, comes nearer to the origin of the properties, and consequently appears to be able to predict the phenomena and predetermine the properties.

All variations of physical, chemical, and electrical properties may eventually be connected to one or the other of these three structures. What cannot be explained by the study of the granular structure may be cleared up by information about the atomic arrangement or even of its inner structure.

As an engineer designs a structure according to the materials available and which he puts together according to technical and scientific rules, so may the metallographist build alloys having predetermined properties by assembling the atoms into desirable crystals and grains.

ALBERT PORTEVIN

Reliability of Oil Tempered vs. Cold Drawn Wire

MUSSELBURGH, *Scotland* — We at the research laboratory of Bruntons Wire Mills have read with very great interest the series of articles on the failure of the heat treated wire first used on the Mt. Hope and Ambassador bridges in the United States, written by the editor of METAL PROGRESS. The articles review very fully all the probable causes of failure which one would look for, and certainly it must be said that this failure remains a mysterious one. As the author of the articles points out, it is not sufficient to say that oil quenched and tempered basic carbon steel wire should not have been used. The point is "Why?" especially when it passes all the specified tests.

Certainly I should never have contemplated using an oil quenched basic steel wire, but I cannot state very definitely why.

I think the idea suggested by some that heat treated steel is unstable is quite erroneous. Alloy steels in this condition have now been in use long enough to prove their stability. Had this been a case of failure several years after erection, one might have considered this possibility seriously, but whatever defect was in this wire must have been inherent right from the beginning.

After all, there must have been locked up stresses in the wire. Such stresses there are undoubtedly in cold drawn wire, but they are not so intensely localized as in quenched material. The stress intensity may be so great in some cases as to produce submicroscopic cracks. Indeed I believe some evidence that this occurs in hardened steel has recently been put forward by Lucas.

It is impossible to say at what stage this bridge wire began to break down. The quenching operation would set up severe internal stresses which would be only partially released by subsequent tempering. There may even have been submicroscopic cracks formed.

Although the ordinary tests such as tensile, torsion, bends, or elongation may generally be expected to reveal any weakness in the material, they do not invariably do so. For example, I have seen samples of wire which appeared to

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be quite ductile under bend and elongation tests which would not stand one torsion and vice versa.

The effect of any stress on a ductile material is to cause strain or deformation, either elastic or plastic. Only one set of conditions will prevent plastic flow in a ductile metal, namely, triple tension (or equal tension along the three dimensions). This condition will eventually overcome the atomic cohesion, and it is not improbable that this condition is always reached before any actual rupture of the metal occurs. So long as the tension is greater in one direction than another, plastic flow will occur.

It is therefore a fair assumption that the additional stress applied in bending the bridge wire round the shoe anchorage resulted, after some time had elapsed for internal adjustment of the locked up stress, in a condition of triple tension causing rupture.

This hypothesis involves the assumption of some inherent weakness in the heat treated wire, due either to locked up stresses or submicroscopic cracking in the original martensite. That such a weakness does as a rule exist in plain carbon basic steel when oil quenched is one of the main causes for the use of alloy steels when quenching is resorted to.

The inherent weakness of heat treated wire appears to be confirmed by the fatigue limit tests at the U. S. Bureau of Standards. Although failure cannot very well be attributed to dynamic fatigue it might reasonably be described as a case of static fatigue.

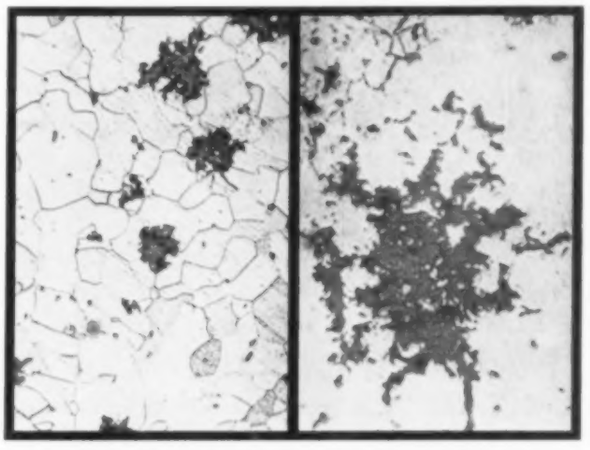
All our experience indicates that better results can be obtained (even for spring wire) with hard drawn patented steel wire than with oil quenched and tempered wire, and this is particularly so with reference to carbon steels. Had an alloy steel been used for this bridge wire, no doubt trouble would not have arisen, but I do not think that even the alloy steel wire would have proved so reliable as the cold drawn wire.

A. T. ADAM

Lapping Retains Graphite

ROLLA, *Mo.* — Since there seems to be an outbreak of methods for polishing cast iron to show the true shape of graphite particles, let me offer two micrographs of malleable iron showing the temper carbon in place. Polishing technique was as follows: Smooth down on 00 emery on a fast wheel; finish on a horizontal polishing lap covered with pitch, using levigated alumina (moistened) for the abrasive. This last step is done on a mechanical wheel, that is, the specimens are put in place and no attention is needed except to take them out when polished.

CHARLES Y. CLAYTON



Malleable Iron Polished on a Lap. Etched sample at 75 diameters; unetched at 125. Black areas usually shown are now gray

Generalized Diagram for Forgeability

SHEFFIELD, *England* — It may be of interest to the readers of METAL PROGRESS to know that the useful formula given by O. W. Ellis in his paper on "Forgeability of Steel" in the September issue can be put into a form enabling its rapid working by graphic methods. His formula, which gives the energy required for stated amounts of deformation of a steel cylinder, is

$$\log E = \log b + (1.56 - 0.47 \log b) \log D$$

The parameter b is clearly the value of the energy E for a reduction D of 1%. The formula can be rewritten

$$3.32 - \log E = a\ (2.13 - \log D)$$

CORRESPONDENCE

where a, the parameter chosen in this equation, is equal to $(1.56 - 0.47 \log b)$. In the imaginary condition when $\log D = 2.13$ (corresponding to a reduction of 134.9%), $\log E$ is 3.32 ($E = 2089$ ft-lb.) whatever the value of a, for then the right side of the second equation vanishes and $\log E$ becomes equal to 3.32. That means that under these conditions all materials coming within the formula at all temperatures would behave alike.

These conditions can only exist in a mathematical sense, but this fact assists the plotting, for on double logarithmic paper, E and D give a straight line, the slope of which is the parameter a.

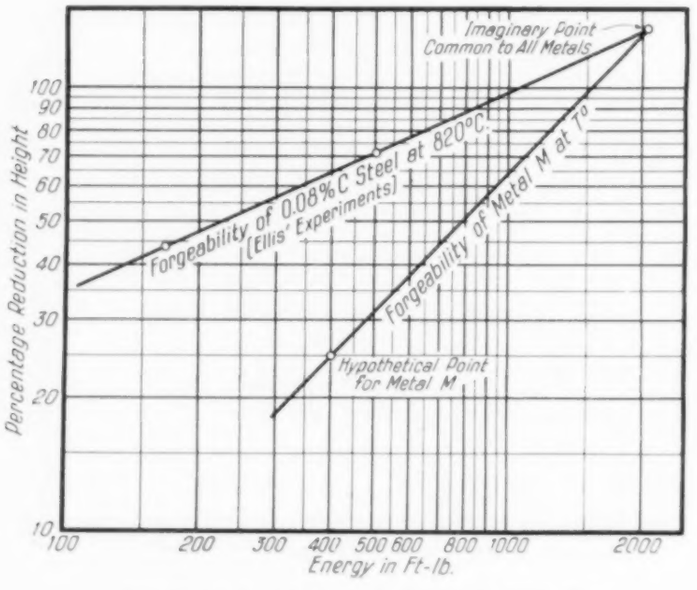
All such lines for all materials and for all temperatures covered by the formula pass, when produced beyond the $D = 100\%$ line, through the point $D = 134.9$, $E = 2089$ ft-lb. This is shown on the attached diagram. It follows that all that is necessary to determine the forgeability of a normal sample of steel at a given temperature is to join up any single accurate observation with this point by a straight line, which shows all corresponding values of deformation and energy for that particular steel and temperature.

The divergence downwards of such lines indicates that when the behavior of any steel at any temperature is being compared with that of the same or any other steel, at the same or any other temperature, the ratio of difference becomes less the larger the amount of deformation on which the comparison is based.

The same limits of applicability naturally apply to the modified formula, and to the plotting, as to the original formula.

It may be of farther interest to know that, according to my own observations at the Hecla Works of Hadfields Ltd., a formula of the same general form applies approximately in the case of copper cylinders tested cold.

S. A. Main



Graph on Log-Log Coordinates, Where Relation Between Energy of Blow and Reduction of Normal ½-In. Sample Plots as a Straight Line

Extensive Study of Axle Failures

Schweinfurt, *Germany* — Axle failures on railroad engines and cars, though seldom discussed, are a subject of more than ordinary importance. American engineers interested in high speed machinery will therefore find much information in a paper by R. Kühnel, Commissioner of German Railroads, which appeared in *Glasers Annalen*, Feb. 15 and March 1, last. The main problem may be stated: Do axles break because of defective material, fatigue, improper design, or some other cause? Dr. Kühnel concludes, from many years' study, that defective material is least often to blame.

Chemical analysis of axles made 40 to 50 years ago and breaking just recently show them to have a fairly wide range of composition: Carbon 0.13 to 0.40, silicon trace to 0.20, manganese 0.20 to 1.15, phosphorus 0.09 to 0.15, and sulphur 0.04 to 0.08. During the early years of this century axles approximated the following: C 0.40, Si 0.30, and Mn 0.70. Manganese is now generally about 1.5%. Physical properties of these steels as quoted are what might be expected.

Dr. Kühnel divides the failures into three groups (*a*) progressive fractures from bending, (*b*) progressive fractures from impact, and (*c*)

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progressive fractures from heat checks.

Fractures of the first group start as fine cracks on the surface which gradually grow inward toward the center until the axle is so weakened that it breaks. From the fact that the failure often does not occur until three-fourths of the axle has gone, it is obvious that the strength of the material is sufficiently high. Unfortunately the appearance of the fracture gives no indication of the time required, but it is generally admitted that the area spreads until the axle breaks.

Neither are progressive impact fractures due to inferior material. Overstressing by the sudden thrust of the brake shoes and the shearing effect on an already defective spot is sufficient. Brakes are used most heavily in switching or on branch lines, so that bad accidents are thus forestalled.

Progressive heat fractures are generally characterized by two or three fracture zones. The outer zone is coarse-grained; it surrounds the smooth-rubbed progressive fracture, and the place where the final break occurs forms the third zone. The explanation advanced is as follows: The surface of the axle becomes heated from defective lubrication and the metal expands considerably. These volume changes produce an abnormally high tensile stress at certain spots; at the same time the resistance is less because the metal is hot, and it cracks. The outer zone is burst so far apart that when the metal vibrates the two sections do not touch each other and so are not polished smooth; the inner portion of the break, on the other hand, does rub and forms a porcelanic surface.

If defective material is not a tenable explanation, the reason must be sought entirely in the location of the cracks, and it is a striking fact that the fractures with very few exceptions occur in the same places to the right and left of the wheel hub.

Locomotive driving wheels are ordinarily keyed and pressed on the axles, as in America. Several broken axles have been examined where the initial cracks are attributed to such a poor fit that the metal surrounding the keyway is overstressed.

As already observed, car axle fractures usually occur just inside the wheel-hub, despite the fact that the shank on the outer side, carrying the bearing, has smaller dimensions. From this Dr. Kühnel believes that both the older and the new materials (one axle which was tested was made in 1882), when properly made and machined, will always be satisfactory.

It is obvious that there must be some special causes which bring about the first cracks on the surface. Two factors can be mentioned: First, the pressure of the shrunk-on hub, and second, the shearing action between the bulky wheel-hub and the slender axle shaft.

In some investigations made elsewhere, it was found that the pressure of a disk on a transmission shaft lowered the torsional strength at least 30%. In some tests in which rings were pressed onto the test specimen, the torsional strength was lowered about 50%. Fracture occurred at the side of the ring toward the center of the bar. These tests exactly parallel the conditions of fracture observed on railroad cars. *(Continued on page 58)*

Brick Lining for a Forge Furnace

ROANOKE, *Va.* — On page 26 of the last issue of METAL PROGRESS, in the third paragraph of our article on "Pulverized Coal for Forge Furnaces" there is a sentence reading: "Hearth is silica sand, and the working space is lined with silica brick." It is true that the hearths of these furnaces are covered with silica sand but the side walls are not lined with silica brick. The forgings heated in these furnaces do not come in contact with the side walls and the chemical action was not thought to be a factor in the selection of refractories.

On account of the high coefficient of expansion of silica brick and the changes in temperatures resulting from intermittent operation, it was thought best to use a first-class clay brick lining. It has a superior resistance to spalling under these conditions.

C. P. BLAIR
C. E. POND

CORRESPONDENCE

TURIN, *Italy* — When the first large electrometallurgical plants were erected in Europe, 30 or 40 years ago, the cost of long-distance power transmission was so high (both because of the high cost of the lines and the loss of power) that the great advantage of locating these plants as near to the power as possible could not be doubted. The cheapest power could be obtained from hydro-electric plants, located in the mountains, far from the most important markets. As a consequence, the selling costs of these products were loaded with the cost of transporting the raw materials to the works, and the products to the consumers. This situation was especially marked in Italy and in France, where most of the power plants were in the Alps.

Migration of Ferro-Alloy Manufacturing

The enormous progress made during recent years in long-distance transmission of power has now completely reversed the original conditions. In most instances, the cost of transmitting power over a given distance is much lower than the cost of transporting raw materials and products.

Such changed circumstances are causing many important changes in the electrometallurgical industry, both in France and in Italy. Plants located in particularly inaccessible places are closing, or greatly reducing their activity, while large new works are being erected in other places.

This movement was started in France a few years ago by companies having works in the Alps (especially in Savoie and Haute-Savoie). A typical case is that of the well-known Société d'Electrochimie et d'Electrométallurgie de Savoie et des Aciéries Electriques d'Ugine. This company recently purchased the Aciéries électriques Paul Girod of Ugine, the largest and best equipped electric steel works in France, long specializing in the manufacture of high quality alloy steels. These steel works had their own hydro-electric power stations nearby and could even sell large quantities of extremely cheap power. But the main sources of supply for raw materials (especially steel scrap and pig iron) and the markets for the products were far distant.

In view of the changing circumstances, above pointed out, the management did not hesitate to erect a large plant in northeastern France, costing much more than the old one. Such a decision could not be made unless the facts stated above had a preponderating influence on the economic location of electrometallurgical plants.

A similar example of the same tendency in Italy is supplied by the new plant erected in Mestre (the industrial section of the port of Venice) by the San Marco Co. for the manufacture of carbide and ferro-alloys.

The capacity of the existing Italian plants for ferro-alloys, calcium carbide, and cyanamid was quite sufficient for the needs of the country when the erection of the new plant was started, and the industrial depression has created a surplus capacity. Under these conditions, the new plant might seem to be uneconomic. But the great majority of the existing plants are located in the Alps, near their hydro-electric plants, yet far from the raw materials (most of which are received by sea from other points along the Italian coast). The power is by no means wasted when a nearby furnace plant is closed, for it can be sold to firms in the industrial districts of northern Italy.

Therefore, to decide whether existing plants are economically sound, it is necessary (according to the old Roman economic principle *res tantum valet, quantum vendi potest*) to take into the cost accounts that price for power corresponding to the price which could be obtained for it in the nearest large place of consumption, after deducting the cost of transmission.

In other words, the advantage of cheap power, which once balanced the high costs of transportation by rail, has now practically disappeared, and the location of works in the Alps no longer corresponds to sound economic principles. On the contrary, under present technical conditions, the location of the new works in Mestre completely fulfills the economic requirements. *(Continued on page 52)*

Making the telephone MORE VALUABLE to more people

The constant purpose of the Bell System is to make the telephone worth more and more to all who use it. To that end eight helpful ways to increase the usefulness of the telephone in your home or office are listed below. . . . Some of these you may know. Others may come as a welcome surprise—as something you often have wished for without knowing it is so readily available.

Extension Telephones. A great convenience in bedroom, kitchen and living-room. Make stair climbing unnecessary. Improve business efficiency in the office. Save many steps every day.

Hand Telephones. Modern. Distinctive in appearance. An attractive addition to any room. Leave one hand free to take notes while telephoning.

Portable Telephones. Plug in the wall like a lamp. May be moved from one room to another as needed.

Individual Lines. Cost little more than party line service. Assure additional privacy. Your line is "busy" only when you use it.

Intercommunicating Facilities. Provide for making calls from one part of the home or office to another or transferring of incoming calls without the aid of the central office operator. Save time and steps and lead to a quiet, smooth-running establishment.

Additional Bell Signals. For use in noisy locations or where it is necessary to summon people from a distance to answer the telephone.

Additional Directory Listings. Enable friends to locate you even though the telephone is in the name of husband, brother or sister, or another relative. In addition to the firm's name, your own can be shown. Direct business to you. The cost is small.

Telephone Planning. The telephone company in your city will gladly assist you in planning the most convenient telephone facilities for your home or office. The services of telephone experts are at your disposal.

Call the Business Office of your Bell Telephone Company for full information about any of the services listed above

AMERICAN TELEPHONE AND TELEGRAPH COMPANY

CORRESPONDENCE

The works are erected in the industrial port itself where raw materials can be unloaded from 10,000-ton steamers into the furnace bunkers. The products are loaded directly on boats or railway cars. The works are only 80 to 120 miles distant from various hydro-electric power stations, supplying current at 200,000 volts. The average costs of production in the new works, including costs of transportation to the main consumers, is estimated to be 20 to 25% less.

The furnaces used here are interesting. Two of them have now been in operation for nearly a year. They are of the Miguet type, with some important modifications necessary on account of their rather exceptional size.

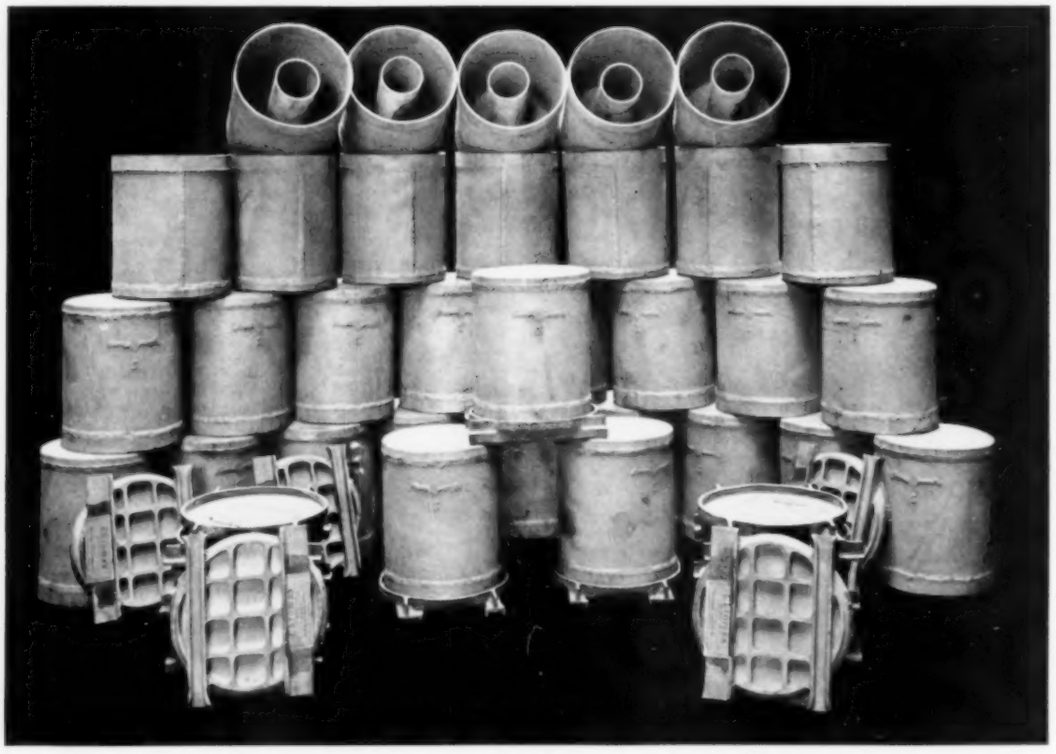
The furnaces are single phase, on Scott connections, and work regularly on 16,000 kw. each. Voltage at the furnace can be changed under load from 25.8 to 57.1 volts, in 56 steps. Current is 350,000 amp. at 42 cycles. Excellent and flexible regulation of voltage regulates the temperature in the furnace in a precise and sure manner.

Electrodes are cylindrical — very large: 13 ft. in diameter (4.05 m.). Being of this quite exceptional dimension, the electrodes are not of a single piece, but are built up with an outside wall of special carbon bricks and filled with a rammed mixture of granular carbon. A system of internal iron rods provides the necessary mechanical strength. Electrodes are lowered automatically as they are consumed. On account of their large size, the movements are very small — usually about 6 in. in 24 hr.

The furnaces are closed; the dust and gases are collected and utilized. This is very important when ferromanganese is manufactured, and the losses of manganese have been reduced practically to zero.

Results obtained with them have been very satisfactory in every respect.

FEDERICO GIOLITTI



"Nichrome" Carburizing Pots — with "Chromax" Trays
made by
DRIVER - HARRIS COMPANY, HARRISON, N. J.

cussed at length in a booklet prepared by that company. Numerous applications of inorganic flux coated electrodes and the advantages in their use are given. Bulletin S-64.

Scleroscopes

The model D standard recording scleroscope is described and illustrated in a recent publication of Shore Instrument Co. The theory and practice of hardness testing with this portable machine as described in this bulletin reveal a fund of valuable facts. Bulletin S-33.

How to Test Wear

Tests of lubricants or of wear of moving parts may be made accurately with a new machine, made by Timken Roller Bearing Co. A bulletin tells how the machine tests the load carrying capacity of lubricants and measures the friction and wear of materials. Bulletin M-71.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. The information given is complete and authoritative. Bulletin S-27.

Dissociating NH_4OH

The production of hydrogen and nitrogen by the dissociation of anhydrous ammonia has definite technical and economical advantages, says a recent publication of Ajax Electric Co. The dissociator is described and its action is clearly explained. Bulletin Ju-83.

Welded Construction

A booklet recently issued by Bethlehem Steel Co. describes the advantages of welded construction in building machinery parts from parts and shapes of rolled steel. The results are said to be sturdier and more economical construction. Bulletin J-76.

Temperature Control

Valuable engineering information on the subject of temperature control is contained in a well-illustrated 48-page booklet published by Foxboro Co. The extensive line of temperature controlling devices manufactured by the company is described. Bulletin S-21.

Q-Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in one of that company's publications. Bulletin D-17.

New Microscope

A new low power binocular microscope is offered to metal men by Carl Zeiss, Inc. A booklet to describe it has been prepared. The new microscope is valuable in examining fractures, surfaces, etc., at magnifications from 4 to 31 diameters. Bulletin MIK-464e.

Recuperators

The complete story of recuperators built by Carborundum Co. for industrial furnaces is told in a readable booklet. The range of types available is described and the operating conditions are outlined in a clear manner. Bulletin F-57.

METAL PROGRESS,

7016 Euclid Ave., Cleveland.

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These results were checked by the Railroad Commission, using the Amsler fatigue testing machine. Test bars were a double cantilever rotating beam somewhat enlarged at the center, and pressed into a sizable block. The steel used in the tests had a tensile strength of 70,000 lb. per sq.in. and an average endurance of 33,000 lb. per sq.in. In specimens where the form of the axle with a standard pressed hub is exactly duplicated, the endurance on the bearing end was found to be 30,000 lb. per sq.in. but only 20,000 lb. per sq.in. on the hub end.

In order to make sure that the shearing effect and not the pressure is the main factor causing the fractures, bars were cut in one piece similar in form to the ones described above, and the test results were duplicated. Experiments with samples where the hub of the pressed-on block was somewhat shorter than the enlarged central portion of the test piece gave endurance limits equal to or greater than the expected strength of the steel under test.

It has been observed that where the end of the hub joins the shaft, a so-called "patina" is formed. Dr. Kühnel ascribes only secondary importance to this patina. The motion of the hub against the axle develops friction and grinds up some of the metal. These finely separated particles oxidize and form rust. These spots, of course, are especially susceptible to corrosion and corrosion cracks cannot be entirely avoided, which are clearly recognized as a source of fatigue fractures.

In conclusion it should be mentioned that an axle stamped with the year 1919 broke in 1931 with an inner progressive fracture across nine-tenths of the section. This fact indicates that inner defects of the steel play only a small part in the durability of the axle, second, that the strength of the material is sufficient in itself, and third, that the prime cause of the fractures is to be found in surface defects or in special surface stresses such as pressure or shear stresses. The construction and form of the joint between wheel and axle should therefore be given the closest attention.

HANS DIERGARTEN

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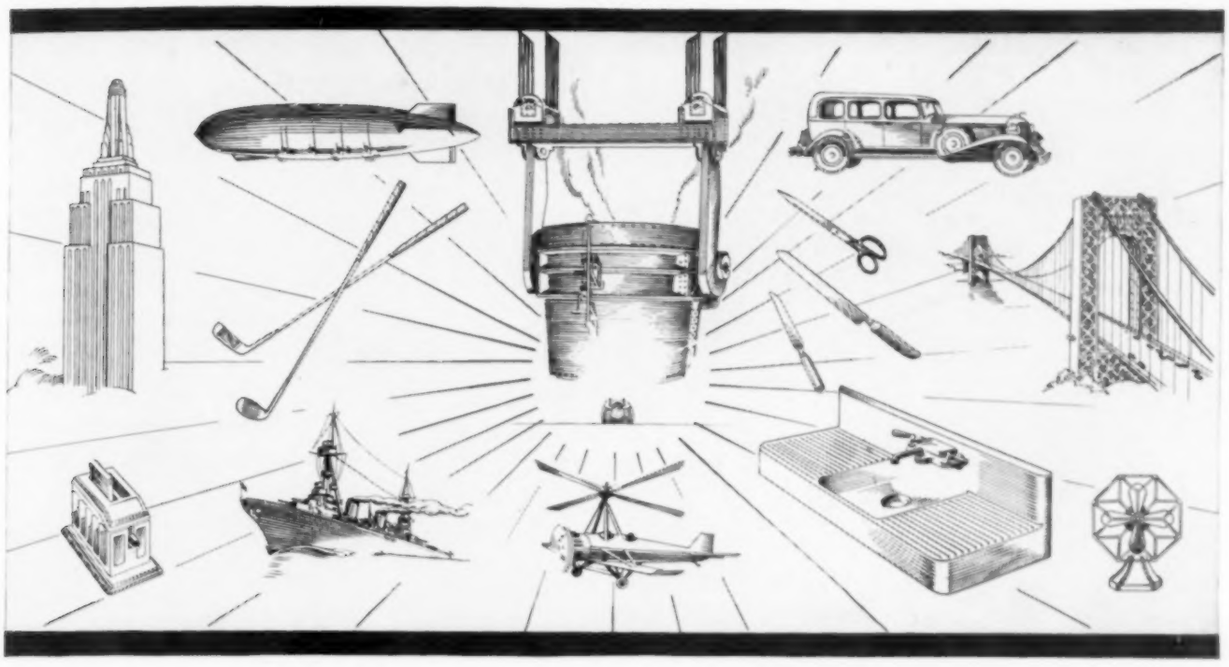

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CUTTING BRASS

(Continued from page 32) it should be high as possible without segregation. This desirable range will be 3 to 3.75%, but the variation in machinabilify of rod containing 2 to 3% lead is less than the variation encountered in an equal range below this figure. The lead should be uniformly disseminated in small particles of similar size. This matter was discussed at considerable length by one of the authors in METAL PROGRESS, May, 1931. O. W. Boston finds that chip laminations from a 3% lead rod are of equal size, while non-leaded or semi-leaded stock give chips of regular size. This has a direct bearing on the finish obtainable.

Copper should be 60 to 63%. The higher the copper content (in this range) the better the rod will machine.

Hardness — Annealed rod will drill approximately 10% faster than rod which has been finished by drawing through a die. However, annealed rod is not always satisfactory for other operations, as it tends to bend away from the cutting tool. Annealed brass also has a greater tendency to burr than hard drawn material. Drill rod is usually finished by reducing cold 20 to 30%, stiffening it sufficiently to stand distortion in handling and machining.

Grain size should be small, as the lead is ordinarily distributed better than in brass with a larger grain size.

Beta constituent should be held at a medium or low figure. Ellis believes that the chip size depends on the proportion of alpha and beta contents, as well as the lead content.

Iron, when present as an impurity, is certainly not harmful.

Aluminum, if alloyed with the brass in small quantities, does not appear to be harmful.

Tin — From a machining standpoint, high tin content is not beneficial, but is often added intentionally to obtain greater resistance to corrosion, higher strength or hardness. The effect of small amounts, present as an impurity, is so slight as to be negligible.

Surface of the rod should be free from physical defects and red stains.